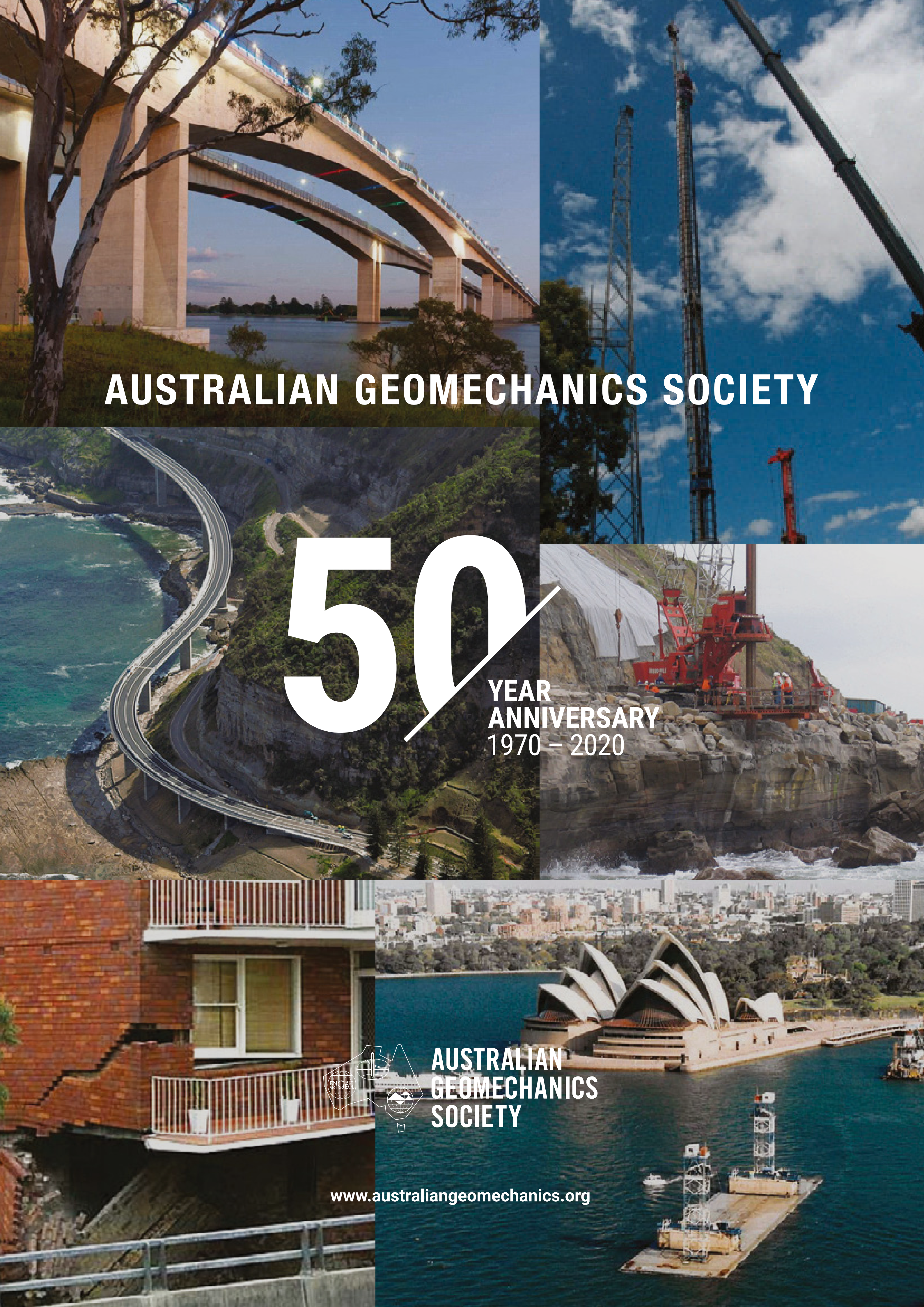

AUSTRALIAN GEOMECHANICS SOCIETY

50

YEAR
ANNIVERSARY
1970 – 2020

AUSTRALIAN
GEOMECHANICS
SOCIETY

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Australian Geomechanics Society 50th Anniversary Commemorative Book

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AUSTRALIAN GEOMECHANICS SOCIETY

50 YEAR ANNIVERSARY
1970 – 2020

COMMEMORATIVE BOOK

EDITED BY TANYA KOUZMIN

CONTRIBUTORS TO THIS BOOK

WHERE'S HARRY?

and.... Alan, Andrew, Bill, Chris, Darren, Garry, Geoff, Graham, Greg, Hugo, Ian J., Ian S., Jack, Jay, John B., John C., John W., John W., Laurie, Mark J., Mark R., Marc, Max, Michael, Neil, Nina, Patrick, Peter H., Peter M., Philip, Robert, Russell, Sam, Sandy, Stephen, Tanya, Ted, Tom, and Tony ?

and.... the teams from each AGS chapter who gave generously of their time, but who are not shown here.

FOREWORD

Welcome to the AGS 50th Anniversary Commemorative book. This book has been written by you, and for you, our Australian geotechnical practitioners and members of the AGS.

The Australian Geomechanics Society (AGS) is a technical society of Engineers Australia (EA), created to promote and advance the theory and practice of geomechanics in Australia. The society was formed in 1970, by a group of dedicated individuals who saw the need for a single group to bring together the fields of soil and rock mechanics as well as civil and mining engineering. Soon after, in 1973, engineering geology was included in the area of practice served by the AGS. The AGS is affiliated with the three associated international societies, namely The International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE), The International Society for Rock Mechanics (ISRM) and The International Association for Engineering Geology and Environment (IAEG).

The geotechnical profession in Australia has continued to grow with the nation over the last 50 years. Exploring our vast land and its varying geology, geomechanics professionals have embraced challenges and developed new approaches to design, incorporating our improved understanding of local conditions. Collaboration between industry and academia has been a great part of these successes; as well as the willingness of the profession to share developments with colleagues in the wider geotechnical community. As the AGS chair and a practising geotechnical professional, I greatly appreciate and admire the accomplishments of those who came before me, and of those who are still expanding our knowledge in all aspects of geotechnics. I am proud to be part of this Australian geomechanics community.

The AGS today is a vibrant society, with approximately 2000 members across Australia. We support a high level of activity including regularly scheduled conferences/symposia, evening technical presentations, a quarterly technical journal, training courses and other continuing professional development (CPD) activities. The AGS is recognised both within Australia and internationally as a highly successful technical society that provides valuable services to the profession.

Over the last 50 years, a large number of volunteers have offered their time to the AGS and have helped it flourish. If asked to write a few words for a journal, book or other publication this will be done, always in good spirit. If there is a need identified to provide technical support/education to the geotechnical profession, or those in related fields, then our knowledgeable colleagues step up and provide courses, author guidelines and update technical standards. On behalf of all AGS members past, present and future, I thank you all for your commitment and support.

The articles included in this 50th anniversary book are one of three types: Chair articles written by every past living chair of the AGS national committee, describing their experience in the role; Project papers written at the invitation of the book committee, by highly regarded "luminaries" of our profession; and Chapter histories written by volunteers on behalf of each of the seven AGS chapters.

The history of the AGS has been set out as a chronological account, separated into chapters that broadly cover one decade. The articles in each chapter are tied loosely together into a theme suggested by the luminary project papers included therein. The first chapter is on the activities of the pioneers of our profession in Australia in the years before 1970, taking us on a journey through to 2020.

My sincere thanks to the editor, Tanya Kouzmin, for her vision for this celebratory book and for her tireless efforts in making this a reality. I also thank the other book committee members (Harry Poulos and Stephen Fityus), for providing assistance to Tanya in the form of brainstorming, proofreading and generally supporting the preparation of the book.

We hope you enjoy this book.

Nina Levy
National Chair, Australian Geomechanics Society

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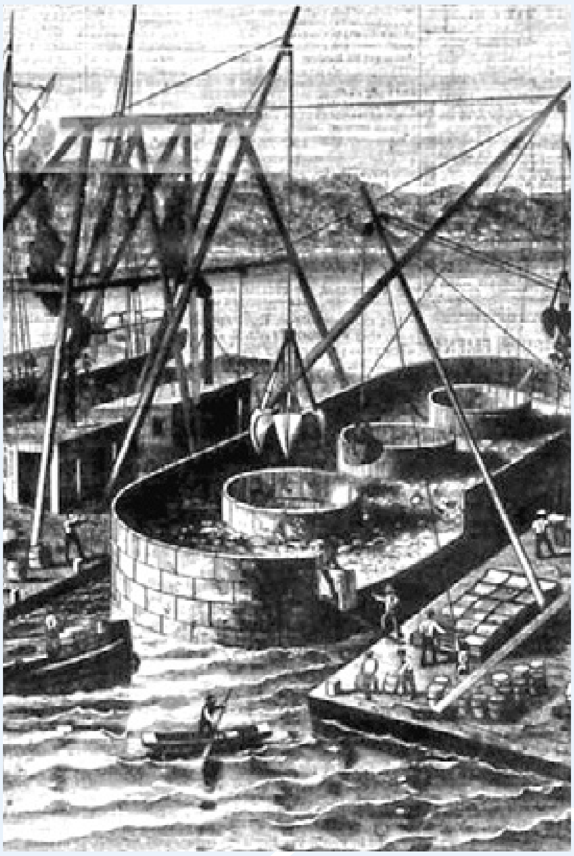
BEFORE 1970 AUSSIE PIONEERS



First railway bridge over the Hawkesbury River, 1889
Artist's rendering of the construction of caisson #6: launched May 9, 1887; bottomed May 11, 1888.
At 162 feet (49.3m) it was the deepest bridge foundation in the world at that time.
Reproduce with the kind permission of Hornsby Shire Recollects, Library & Community Services, Hornsby Shire Council.

Various elements of what we now know as geotechnical engineering had been incorporated into civil and mining engineering projects in the 19th century and the first half of the 20th century. Water supply tunnels, dams, roads, building foundations and coal mines were among these projects. However, university courses in those earlier times did not overtly include geotechnical engineering as a subject, and it was only in the 1950's that the systematic teaching of one component of geotechnical engineering, soil mechanics, commenced. The main stimulus for this development was the arrival in Australia from Great Britain of two engineering academics, Hugh Trollope and Edward Davis. They taught at the Universities of Melbourne and Sydney respectively, and set in motion teaching and research in soil mechanics that has subsequently blossomed into the broader field of geotechnical engineering. This chapter provides some details of these, and other, pioneers, and describes some of the landmark projects which contributed to the growth of what is now a critical technical component of Australia's economic and intellectual wealth.

THE EARLY DAYS

PROFESSOR
HARRY POULOS AM

Professor Harry Poulos has been active in promoting geotechnical education, in undertaking and supervising geotechnical research and in applying the results of this research into practice as a high-level consultant. He has developed particular expertise in pile foundation design for high rise buildings. His efforts have been recognized by the award of the Kevin Nash Gold medal in 2005 by the International Society for Soil Mechanics and Geotechnical Engineering.

He has given the Terzaghi and Rankine Lectures, and is a Fellow of the Australian Academy of Science, a Fellow of the Australian Academy of Technology and Engineering, an Honorary Fellow of the Institution of Engineers Australia, a Distinguished Member of the American Society of Civil Engineers, and a Foreign Member of the US National Academy of Engineering.

BEFORE 1970

1 INTRODUCTION

This chapter will attempt to trace the early days of Geomechanics in Australia, prior to and up to the formation of the Australian Geomechanics Society (AGS) in 1970. It is by no means a comprehensive history of the subject, but rather a collection and distillation of some available information. I will attempt to consider this information chronologically, starting with the pre-1950s, and then proceed to cover each succeeding decade until the formation of the AGS at the beginning of the 1970s decade. My own personal experience dates back only to the 1960s, and I will attempt to provide some of my own recollections from those days and then from subsequent periods into the 1980s.

A very valuable source of information that I have drawn upon is the paper by Brown (1991) which discusses Australian advances in geomechanics, but which also covers some of the early pioneers and their contributions to our discipline.

2 THE PRE-1950s

Brown (1991) indicates that the first major engineering projects in Australia with significant geomechanics components were the construction of roads leading west, north and south from Sydney in the decade 1810-1820, and the excavation of the 3.6 km long water supply tunnel called Busby's bore in Sydney in the period 1827-1837. Robert Hughes, in his historical exposition of early Australia, "The Fatal Shore", gives the following indication of the rigours of early foundation construction in the colonies:

"By far the worst work was driving piles, under water and in chains, for the slipways. If that did not break a man down, he could be left overnight on tiny Grummet Island, half a mile off Sarah Island".

While much of the early application (albeit unwittingly) of geomechanics was to civil projects, Brown (1991) also mentions that the mining industry provided a stimulus in later years for the development of geomechanics as applied to mining and the winning of natural resources.

By the dawn of the 20th century, the social conditions had improved vastly, and construction projects proceeded in a far less onerous manner. The formation of the Institution of Engineers Australia (IE Aust) in 1919 heralded a new era of organization in the engineering industry. This was an amalgamation of 12 existing engineering societies in Australia, and Corbett (1973) sets out the history of IE Aust and some details of its founders. The first council meeting was held in 1919, electing Professor William Warren of the University of Sydney as the first President. On 1 May 1926 the Institution was incorporated as a company limited by guarantee and on 10 March 1938 King George the Sixth granted a charter of incorporation to the Institution, reconstituting it as a body corporate and politic by Royal Charter.

The Institution provided a forum for the publication of technical papers in Australia, and a number of papers related to geomechanics started to appear in its transactions. Brown (1991) lists some important early papers, by the following authors:

- Hawken (1925), who published a lengthy analysis of the earth pressure problem;
- Ross (1927) and Hawken (1928, 1930), who published further papers on that general topic including details of experiments on sand;
- Ritchie (1930), who wrote a paper on rolled earthfill dams;
- Isaacs (1931) who published a paper on the analysis of pile driving considering the transmission of waves along the pile. This paper pre-dated by almost a quarter of a century the work carried out in the USA by E A L Smith (1955) who developed a numerical solution of the one-dimensional wave equation, and is commonly credited as being the pioneer of this approach to pile driving analysis.

A major event occurred in 1936 when the First International Conference on Soil Mechanics and Foundation Engineering was held at Harvard University in the USA. No Australians published a paper in that conference, but at the following International Conference held post-war in Rotterdam in 1948, six Australians presented a total of nine papers. Brown (1991) states that, at that conference, there were reported to be nine soil mechanics laboratories in Australia, all in public works authorities except for that at the Division of Soils, CSIR, in Adelaide.

It is clear that there was an accelerating pace of interest and development in the geomechanics area following the formation of IE Aust, but at the same time, there does not appear to have been any formal teaching of the subject in Australian Universities. That situation was to change significantly in the following decade.

3 THE 1950s AND THE AUSTRALIAN PIONEERS OF GEOMECHANICS

During this decade, geomechanics in Australia received a major stimulus with the arrival, from the United Kingdom, of two of the three pioneers of our profession, Professor Edward Hughesdon (Ted) Davis and Professor Hugh Trollope. Their long-term impact and that of the third pioneer, Dr Gordon Aitchison, was substantial, and it is therefore appropriate to describe in some further detail these men and their achievements.

3.1 Professor Ted Davis

E H (Ted) Davis is shown in Figure 1 in a typical 1950s academic pose with pipe in mouth. Edward Hughesden Davis was born in Hendon England on 16th December 1920, and died in Sydney Australia on 26th February 1981. Davis joined the University of Sydney in 1952 and started the systematic teaching of soil mechanics. He made major contributions to soil mechanics, the theory of plasticity, the theory of elasticity as applied to soils, and the theory of consolidation. His contributions were recognised by his election to the Australian Academy of Science. He also acted as a consultant on several important projects and was a specialist consultant for the firm of Coffey and Hollingsworth in the 1970s and early 1980s.

Davis' work on the application of plasticity to soil stability problems is of particular note, and was well-described in his widely acclaimed chapter (Davis, 1968) in the book edited by I K Lee (1968). His work on non-linear consolidation theory was also highly influential and helped to explain circumstances in which the classical theory of Terzaghi (1925) gave inaccurate predictions of the rate of consolidation of a soil mass. His application of analytical and numerical methods to stability and settlement problems was to lead to a flourish of research into foundation bearing capacity and foundation settlements at the University of Sydney.

Figure 1: Professor E.H. (Ted) Davis (1920-1981)

Among his protégés were the late Don Douglas, Harry Poulos, the late John Booker, John Carter and Kerry Rowe.

His biography from the Encyclopaedia of Australian Science is reproduced below:

> *Born Hendon, England, 16 December 1920. Died Sydney, 26 February 1981. Educated University of London (Bachelor of Civil Engineering 1940). Design and supervision of civil engineering works with Sir Alexander Gibb and Partners then with Dr Oscar Faber 1940-42; war service 1942-46; senior scientific officer, Road Research Laboratory 1947-50; lecturer, University College London 1950-52; senior lecturer, University of Sydney 1952-63, Associate Professor of Soil Mechanics 1963-68, Professor of Civil Engineering (Soil Mechanics) 1968-79, Challis Professor and Head, School of Engineering 1979-81. Fellow, Australian Academy of Science 1980; inaugural John Jaeger Memorial Medal, Australian Geomechanics Society 1980. Helped to establish Sydney Soil Mechanics Group and Australian Geomechanics Society; Australian vice-president, International Society of Soil Mechanics 1969-73.*
>
> *Edward Davis was Challis Professor of Civil Engineering, University of Sydney 1968-1981. He used theoretical methods to analyse geotechnical problems, particularly in the following areas: road pavement behaviour and design; application of plasticity theory to soil and rock stability problems; application of elasticity theory to soil and rock problems; and theory of consolidation of clay soils.*

Roderick (1982) provides a more complete biography of Davis.

3.2 Professor David Hugh Trollope

D.H. (Hugh) Trollope is pictured in Figure 2. He was born in Swansea Wales on 9th March 1925 and died on 8th March 2011 in Bendigo Victoria. He migrated to Australia and joined the University of Melbourne in 1950. He started the teaching of soil mechanics at that University and developed a strong research group. In the 1960's, he moved to James Cook University in Queensland to take the position of Foundation Professor of Civil Engineering, and later became Deputy Vice-Chancellor, while still maintaining his technical interests in soil and rock mechanics.

Figure 2: Professor D H Trollope (1925-2011)

Trollope made major contributions to arching in soils, and pioneered the area of "clastic mechanics", which found application in the emerging field of rock mechanics as well as in traditional soil mechanics. Brown (1991) points out that, in the first PhD thesis on a geomechanics topic submitted to an Australian University, Trollope (1956) developed a theory of the mechanics of discontinua. Trollope's initial theoretical and experimental studies of the stresses under a wedge of sand were extended subsequently to a wider range of geomechanics problems in which the particulate nature of soil and rock masses was modelled explicitly (Trollope 1968). The lack of computational power available at the time of its development limited the utility of Trollope's pioneering approach but other methods, notably Cundall's distinct element method, subsequently found wider recognition and application. Nevertheless, Trollope was one of the first individuals to insist on the need to consider the particulate nature of geomaterials and to develop a systematic theory of discontinua. His pioneering contributions have probably not been accorded the international recognition that they merit.

His contributions to the university and to his profession were recognised by his appointment as an Officer of the Order of Australia (AO). Among his protégés were Ted Brown, Jack Morgan, Ian Lee, Dick Parry, Alan Parkin, Robin Friday and Kevin Rosengren.

His entry in the Encyclopaedia of Australian Science is shown below:

> *Born Swansea, Wales, 9 March 1925. AO 1989. Educated Universities of Wales (MSc 1946) and Melbourne (PhD 1956). DEng (Qld) 1966. Research Assistant, Royal Aircraft Establishment Farnborough 1944-46; Municipal Engineer Country Borough of Swansea 1946-47; Assistant Lecturer, Department of Municipal Engineering, University of Manchester 1947-50; Lecturer, Senior Lecturer, Reader in Civil Engineering, University of Melbourne 1950-64; Foundation Professor of Civil Engineering, James Cook University of Northern Queensland 1964-87, Pro Vice-Chancellor 1973-77, Deputy Vice-Chancellor 1977-87. Warren Memorial Prize, Institution of Engineers Australia 1966; Fellow, Australian Academy of Technological Sciences and Engineering 1983; Kernot Medal, University of Melbourne 1984. Foundation Chairman, Australian Geomechanics Society 1970-72.*

3.3 Dr Gordon Aitchison

The other pivotal figure in Australian Geomechanics in the 1950s was Dr Gordon Aitchison, who is shown in Figure 3. Aitchison, along with Davis and Trollope, comprised the triumvirate of geotechnical engineers that was so influential in developing soil mechanics and geotechnical engineering in Australia.

Figure 3: Dr Gordon Aitchison (1918-2003)

Gordon Aitchison made major contributions to the mechanics of unsaturated soils and developed a very strong research group within the then CSIRO Division of Geomechanics in the 1960s and 1970s. Among his protégés were the late Ian Donald, and Brian Richards.

His biographical details are as follows:

> *Born 6 March 1918 in Adelaide, South Australia, Australia. Died June 2003 Mornington, Victoria, Australia. He was educated at the University of Adelaide and University of Melbourne.*

He was Chief, Division of Applied Geomechanics, CSIRO, during the period 1967-1978. From 1957 to 1961, he was the Inaugural Australasian Vice-President International Society Soil Mechanics and Foundation Engineers. From 1959 – 1967, he was Officer-in-charge of the Soil Mechanics Section CSIRO (Commonwealth Scientific and Industrial Research Organisation), and in 1967, became Chief of the CSIRO Division of Applied Geomechanics, a position he held until 1978.

During that period, he was also Chairman of the Institute of Publicity and Exchange Geomechanics Computer Programs for the International Society for Soil Mechanics and Foundation Engineering (ISSMFE). From 1980 to 1982, he was the President of the Royal Society of Victoria.

3.4 Some Pioneers in the Commercial Area

Much of the early activity in Australian geomechanics was centred in Universities and in the CSIRO, but as the decade progressed, geomechanics in the commercial area started to develop. Two examples of pioneers in this development were Daniel (Danny) Moye, who worked on the iconic Snowy Mountains Hydroelectric Scheme, and David Coffey, who started what appears to be the first local consulting company specialising in soil mechanics.

Danny Moye, pictured in Figure 4, is widely considered to be the godfather of engineering geology and rock mechanics in Australia. He developed structured approaches to the collection of geological data and classification. Moye published accounts of the way geology was applied during the planning and construction of dams, tunnels and power stations. Most of the principles and techniques of engineering geology described in these accounts are still accepted worldwide today. Figure 5 shows an example of the type of geological section that he developed.

Figure 4: Daniel Moye

Altogether 36 geologists and geophysicists worked under Moye's direction and guidance, with a peak of 13 between 1958 and 1962. He developed project teams which worked with and earned the respect of the Scheme's engineers. He acted as a mentor to several persons who later became well-known in their own right, including Peter Burgess and the late Dr Barry McMahon. Tragically, Moye, his wife Joan, and youngest child Helen, died as a result of a car accident on 7 January 1975.

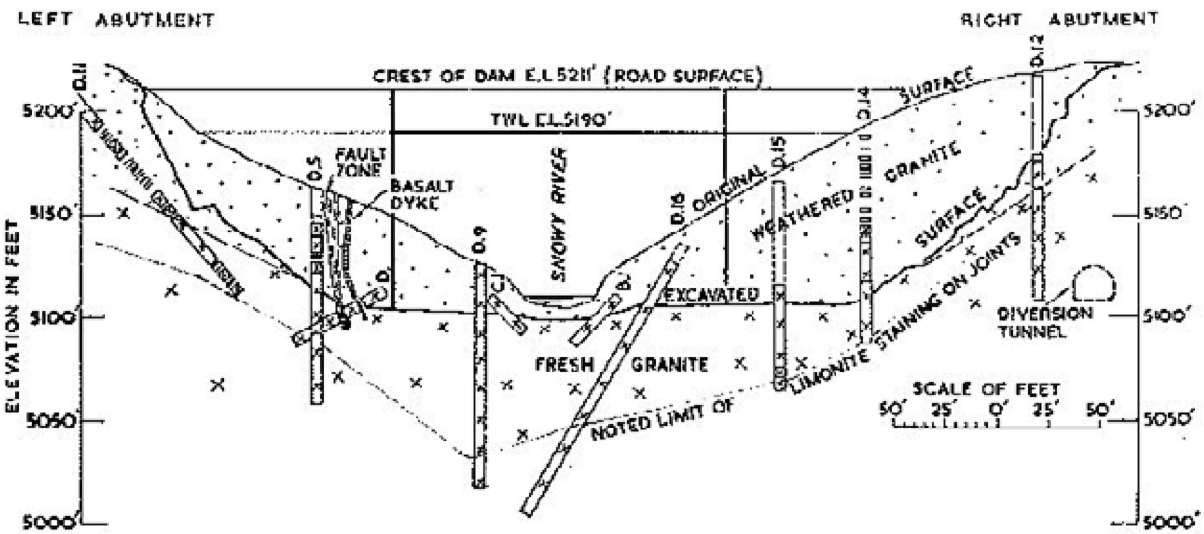


Figure 5: Typical example of a dam site cross-section by Moye

Figure 6: David Coffey

David Coffey graduated in Engineering from the University of Sydney in 1948, and joined the Public Works Department of NSW in 1950 which led him to work on the Snowy Mountains Scheme. Here he was put in charge of investigation of materials and testing. With no formal education in earth and rock materials, Coffey taught himself through reading text books on the subject. These origins provided the platform for Mr Coffey's lifelong career in soil mechanics and foundation engineering. After spending some time in Canada, he returned to Australia to set up his own consulting company in 1959. He commenced his practice in geotechnical work from his home in St Ives and from this humble beginning, proceeded to pioneer the geotechnical consulting profession in Australia.

As the company grew, it expanded into the South East Asian region, providing services following Australian Aid grants and other international loans. David Coffey continued as Chairman of Coffey International until 1984, when he retired from the business. In 1998, the Australian Geomechanics Society presented David Coffey their most prestigious award, the John Jaeger Memorial Medal, in recognition of his contribution to the Geomechanics development and practice in Australia. In 2015, he was awarded an Honorary Doctorate in Engineering from the University of Sydney for his contributions to the profession. Figure 6 shows a portrait of David Coffey painted in 1995 by the artist Dimitri Likachov.

Another person of note, not strictly in the commercial area but within a state government department, was Milton G. Speedie. He had written a thesis entitled "Earthen Dams" for which the University of Melbourne awarded him a Masters degree. This publication demonstrated the use of flow nets, stress distribution, and stability analysis as applied to earth dams. He worked with the Victorian State Rivers and Water Supply Commission, and undertook a study tour to the USA in 1948. His report: "American Practice in Dam Design and Construction", was published in the Commonwealth Engineer, November and December 1948. He undertook a further trip to the USA and Canada in 1970 as part of a dam design and construction mission, and attended the 10th Congress on Large Dams in Montreal, Canada. He was influential in the development of systematic approaches to the design and construction of earth dams in Australia.

Mention should also be made of two other commercial pioneers, who, although they started their businesses well after the 1950's, started their careers in that era, and who have companies that have endured and remained Australian-owned. The first is John Wagstaff, pictured in Figure 7, who started his company Wagstaff Piling in 1980. The company remains Australian-owned and specialises in precast piling, dynamic testing, and ground improvement techniques. John has invested consistently in research and new technology for his business.

Figure 7: John Wagstaff

Don Douglas, shown in Figure 8, graduated from the University of Sydney in 1955 and subsequently was the first post-graduate student to be supervised by Ted Davis. After a period working with Ground Test, Don started his own company in 1983, a company that is now called Douglas Partners and one which is one of the key geotechnical firms in Australia. Unfortunately, Don died suddenly of a heart attack in December 1994, a loss that was felt widely throughout the geotechnical community.

Figure 8: Don Douglas

4 THE 1960s

4.1 Local Soil Mechanics Groups

As mentioned previously, the International Society for Soil Mechanics and Foundation Engineering (ISSMFE) was formed in 1936 and provided an early focus for geotechnical activity in many parts of the world, including Australia. Local groups were formed in Sydney and in Melbourne and were involved in the organization of various seminars and conferences, including the 1960 3rd Australia-New Zealand Conference on Soil Mechanics and Foundation Engineering in Sydney, under the chairmanship of E H Davis. This preceded my direct involvement in soil mechanics, although I do recall that Davis' lectures in Soil Mechanics II, which I was attending, were occasionally postponed due to his organizational responsibilities.

My first direct involvement with the Sydney Soil Mechanics Group was on July 30th 1963, when I presented my first seminar on three-dimensional consolidation of clays. Figure 9 shows the first page of a handout to the brave attendees, requiring a level of tolerance that would be well beyond many present-day audiences. Nevertheless, the level of enthusiasm of the Sydney Group appeared undiminished, as E H Davis gave a talk on the non-linear theory of consolidation just five days later (Figure 10).

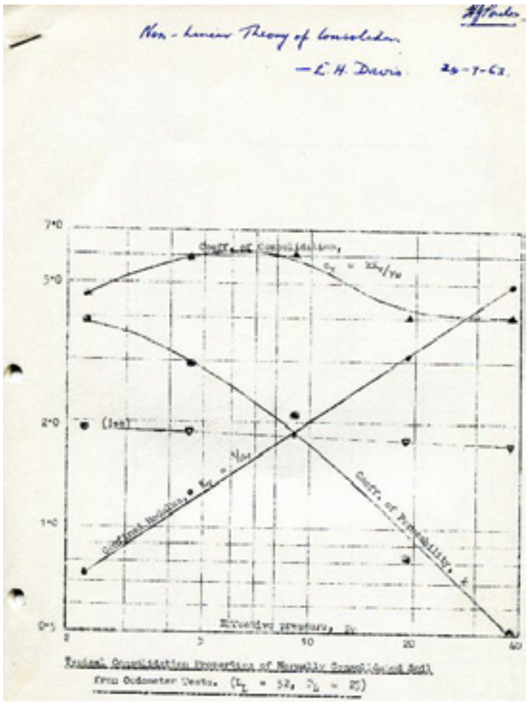
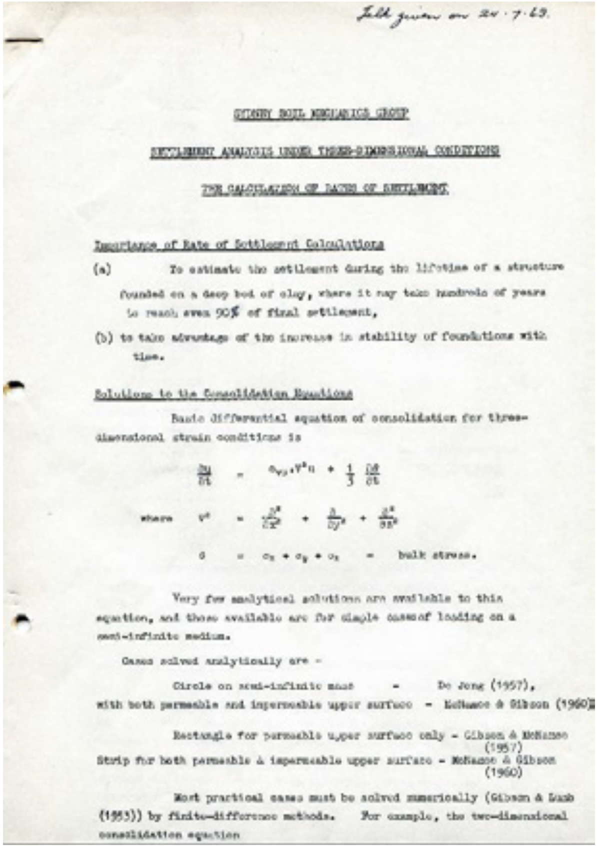


Figure 9: Front page of a handout at a seminar given by H. G. Poulos in July 1963



SYDNEY SOIL MECHANICS GROUP

SETTLEMENT ANALYSIS UNDER THREE-DIMENSIONAL CONDITIONS

THE CALCULATION OF RATES OF SETTLEMENT

Importance of Rate of Settlement Calculations

(a) To estimate the settlement during the lifetime of a structure founded on a deep bed of clay, where it may take hundreds of years to reach even 90% of final settlement,

(b) to take advantage of the increase in stability of foundations with time.

Solutions to the Consolidation Equations

Basic differential equation of consolidation for three-dimensional strain conditions is

$$\frac{\partial u}{\partial t} = c_{v3} \cdot \nabla^2 u + \frac{1}{3}\frac{\partial \theta}{\partial t}$$

where $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$

$\theta = \sigma_x + \sigma_y + \sigma_z$ = bulk stress.

Very few analytical solutions are available to this equation, and those available are for simple cases of loading on a semi-infinite medium.

Cases solved analytically are –

Circle on semi-infinite mass – De Jong (1957), with both permeable and impermeable upper surface – McNamee & Gibson (1960)

Rectangle for permeable upper surface only – Gibson & McNamee (1957)

Strip for both permeable & impermeable upper surface – McNamee & Gibson (1960)

Most practical cases must be solved numerically (Gibson & Lumb (1953)) by finite-difference methods. For example, the two-dimensional consolidation equation

Figure 10: Lecture by E.H. Davis 29 July 1963

Under the guidance of Davis and Trollope, local groups began to hold technical meetings in Sydney and Melbourne, and their protégés began to participate in these meetings. Examples of the talks given in Melbourne are:

- "Foundation design with particular reference to the Melbourne area", given in Melbourne by I K Lee in 1968;
- "Soil shrinking and swelling characteristics", given by I B Donald in Melbourne in 1968.

4.2 The Genesis of Short Courses

The latter two papers were part of a Specialty Seminar on Foundation Design, organised in Melbourne in 1968, but prior to that event, a short course was held at the University of Melbourne in February 1966 under the direction of Dr Ian K Lee. This was the first course to which I contributed, and it was subsequently expanded and edited by Lee, and published by Butterworths as "Soil Mechanics – Selected Topics" (see the well-used copy in Figure 11). It was, in many ways, a pathfinder in the evolution of specialist books on soil mechanics and foundation engineering.

Ian Lee moved from the University of Melbourne to the University of Sydney in 1967, and with Ted Davis, organized a short course on settlement analysis and consolidation there in 1968.

Subsequently, Lee moved to the University of New South Wales in 1971, and directed another short course which, amongst other topics, introduced probabilistic methods to those involved in soil mechanics, via Peter Lumb of the University of Hong Kong.

Material from this course was published by Butterworths in 1974 in another book edited by Lee, entitled; "Soil Mechanics – New Horizons".

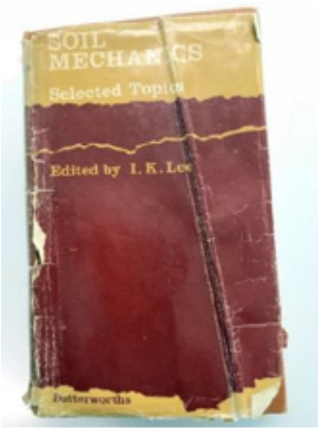


Figure 11: Soil Mechanics – Selected topics, by I. K. Lee (very well-used)

In 1972 at the University of Sydney, Ted Davis and the author held a 5-day course on "Analysis and Design of Pile Foundations". The course was well-attended, and the content of that course was eventually published by John Wiley and Sons in 1980 as "Pile Foundation Analysis and Design", co-authored by Poulos and Davis.

While Short Courses are now commonly offered by several commercial and professional organizations, the early courses centred around universities and were influential in the spread of specialist knowledge to the geotechnical profession.

5 THE EMERGENCE OF GEOTECHNICAL CONFERENCES IN AUSTRALASIA

Australasia can proudly claim to have organized the first regional conference of ISSMFE in 1952. Dr Hugh Trollope was the key figure in organising this conference, which focussed on the shear strength of soils and which was held in Melbourne under the auspices of the Department of Civil Engineering of the University of Melbourne and the Institution of Engineers Australia.

This conference was reviewed in Geotechnique in March 1953, and parts of this review are reproduced in Figure 12. It highlighted the issue of unsaturated soils which became a major topic of research in Australia over the next two decades.

At the conclusion of the conference it was decided that it should be referred to as the First Australia-New Zealand Conference on Soil Mechanics and Foundation Engineering and that further conferences should be held at regular intervals thereafter. Subsequently, a series of quadrennial Australia-New Zealand Conferences has been maintained ever since. These conferences were held in Australia and New Zealand, with a pattern of two conferences in Australia and one in New Zealand. Table 1 lists these conferences, and it can be noted that the name of the conference changed in 1971, following the formation of the Australian and New Zealand Geomechanics Societies.

From a personal viewpoint, I have recollections of all but the first two conferences. During the 1960 conference in Sydney, I was in my final undergraduate year, and Ted Davis was the chair of the organising committee of the conference. I recall that, just before and during the conference, some of our lectures in soil mechanics were postponed and re-scheduled because of Davis' commitments with the conference. The 1963 conference in Adelaide was my first experience of an Australia-New Zealand Conference, and where I published my first paper, jointly with Davis, on "Triaxial Testing and Three-Dimensional Settlement Analysis". The 1967 conference in Auckland provided me with my first opportunity to visit New Zealand and was also the venue for my first "solo" conference paper on "The Use of the Sector Method for Calculating Stresses and Displacements in an Elastic Mass".

A REVIEW OF THE FIRST AUSTRALIA – NEW ZEALAND CONFERENCE ON SOIL MECHANICS AND FOUNDATION ENGINEERING

by

D. H. TROLLOPE, M.Sc.

The Conference was held at the University of Melbourne, during the week commencing June 2nd, 1952, under the auspices of the Faculty of Engineering of the University, and the Institution of Engineers (Australia). The subject of the Conference was "The Shear Characteristics of Soils" on which the following Papers were presented :—

(1) "The Chemistry of Soils" .. .. Assoc. Prof. G. W. Leeper
(2) "The Movement of Water in Unsaturated Soils" .. .. J. W. Holmes
(3) "A Note on the Physical Aspect of Cohesion" .. .. D. H. Trollope
(4) "The Physical Condition of the Soil as a Modifying Factor in the Measurement and Interpretation of Shear Strength" G. D. Aitchison
(5) "Physical Properties of Volcanic-Ash Soils and their Shear Characteristics" .. .. K. S. Birrell
(6) "The Basic Law of Shear Strength" .. .. D. H. Trollope
(7) "Shear Resistance of Soils" .. .. J. McN. Turnbull

CONCLUSIONS

In the Writer's opinion, the conclusions to be drawn from the Conference are twofold. First, particularly in Australia, the influence of environment on soil behaviour is of vital importance. Considerable attention needs to be paid to the shear characteristics of soils in the unsaturated state, both remoulded and undisturbed. Secondly, the definition of cohesion as a fundamental soil property is one about which, at present, there is much conflicting opinion ; engineers are dependant to a large extent upon progress in the science of colloid chemistry for resolution of this problem. Close collaboration between the two branches is essential, however, to bring about the attainment of this end.

The Proceedings of the Conference will be published, early in 1953.

Figure 12: Review of 1st ANZ Conference, in Géotechnique, March 1953

Table 1: Australia New Zealand Regional Conferences (1952-1971)

Conference	Location	Year
1st ANZ Conference SM&FE	Melbourne	1952
2nd ANZ Conference SM&FE	Christchurch	1956
3rd ANZ Conference SM&FE	Sydney	1960
4th ANZ Conference SM&FE	Adelaide	1963
5th ANZ Conference SM&FE	Auckland	1967
1st ANZ Conference on Geomechanics	Melbourne	1971

The 1971 conference in Melbourne, the first to be "badged" as a "Geomechanics" conference, and the first after the formation of the Australian Geomechanics Society, was particularly memorable, as it was attended by a number of luminaries in the soil mechanics world who had been in Sydney for a Board Meeting of the ISSMFE. These included the President, Professor Ralph Peck, the Secretary General, Professor Kevin Nash, the keynote speaker, Professor T William Lambe, and Professor Kenji Ishihara of Japan. They were transported from Sydney to Melbourne by two cars, one driven by Ted Davis, and the other by Denis Hodgson, who was then with the Sydney office of the consulting firm of Dames and Moore. The trip was over two days, with an overnight stop at the town of Merimubula on the south coast of New South Wales. On the second day, I shared the driving with Denis Hodgson, with the weighty responsibility of delivering the most prominent member of our profession, Professor Ralph Peck, safely to his hotel in Melbourne. I am pleased to report that this was done successfully, although not without extended periods of high anxiety.

Figures 13 and 14 show photographs taken during the journey to Melbourne.

Figure 13: On the road to Melbourne. From left to right: Kevin Nash, Mrs Davis, Ted Davis (obscured), Ralph Peck, Mrs Lambe (obscured), Denis Hodgson

Figure 14: On the road to Melbourne. From left to right: Ted Davis, Bill Lambe

6 INTERACTION WITH INTERNATIONAL SOCIETIES

The oldest of the international societies, originally called the International Society for Soil Mechanics and Foundation Engineering (ISSMFE), was formed in 1936. It had its origins in the First International Conference on Soil Mechanics and Foundation Engineering (ICSMFE) held at Harvard University in Cambridge Massachusetts in 1936. A total of 206 delegates attended from 20 countries. In order to ensure continuation of this very successful initiative, an Executive Committee was set up with Karl Terzaghi as President and Arthur Casagrande as Secretary. Because of the Second World War, the Second ICSMFE was not held until 1948 in Rotterdam. Again this proved to be a great success, with 596 delegates. By the time of the Third ICSMFE in Zurich in 1953, the International Society had become firmly established, with Terzaghi as President and Donald Taylor as Secretary. In 1957 A W Skempton became President, and the Secretariat moved to the UK. Since 1965, the Secretaries General have been J K T Nash (1965-1981), J B Burland (1981), R H G Parry (1981-1999) and R N Taylor (1999-present). The quadriennial ICSMFE followed an established pattern from 1953 and the Jubilee Conference was held in San Francisco in 1985, attracting 2000 delegates and guests. In 1997, the Council approved a change in name to the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) to reflect more accurately the broadened activities of the Society.

Local Groups in Australia and New Zealand became affiliated with ISSMFE in the late 1950s. They joined together to become one of the Society's 6 Regions. The Australasian Region so formed comprises only the two member societies. There remains close cooperation between the two societies and also an agreement in relation to the election of regional Vice-Presidents, in that the Australian Society will make a nomination for two successive terms and then the New Zealand Society will make the nomination for the next term. While it has been customary for each Society to nominate from its own members, this has not always been the case, and there are at least two cases in which a nomination of a member of the other Society has been made.

Table 2 lists the official Australasian Regional Vice – Presidents. There is an indication that, during the period 1953-57, J M Lee was the Vice-President, but it is understood that this was not an official nomination. It can be noted that three of the Australian pioneers held the Vice-Presidential role in the first four periods of office in the Australasian Region.

Table 2: Australasian Vice-Presidents of ISSMFE /ISSMGE to 1973

Name	Country	Period of Office
G.D. Aitchison	Australia	1957-61
J. Birrell	New Zealand	1961-65
D.H. Trollope	Australia	1965-69
E.H. Davis	Australia	1969-73

Brown (1991) states that, with the emergence of rock mechanics as an identifiable discipline, the International Society for Rock Mechanics (ISRM) was formed in Salzburg in 1962 and held its first International Congress at Lisbon in 1966. Its foundation is mainly owed to Prof Leopold Müller who acted as President of the Society until September 1966. The field of Rock Mechanics is taken to include all studies relative to the physical and mechanical behaviour of rocks and rock masses and the applications of this knowledge for the better understanding of geological processes and in the fields of Engineering. The first Australasian Vice-President of ISRM during the pre-AGS years was Lance Endersbee, who held office from 1966 to 1970.

Also notable is the fact that Professor Ted Brown became the first Australasian President of an international geotechnical society when he was elected ISRM President for the period 1983-1987. A complete table of ISRM Australasian Vice Presidents over the period 1970 to 2020 is given in the final chapter of this book.

In the 1960s, the International Association for Engineering Geology (IAEG) was also formed. This arose from an initiative at the 22nd International Geological Congress in New Delhi in December 1964, and the Association was formed a few days later. A more detailed history of the development of IAEG can be found in the 50th anniversary volume produced by IAEG, entitled "The International Association for Engineering Geology and the Environment – 50 Years 1964-2014", published by Science Press, Beijing.

Australia's Dr Fred Baynes was elected as President for the period 2007-2010. Earlier, Dr Owen White, Australian-born but a Canadian citizen, was IAEG President from 1987 to 1990. A complete table of IAEG Australasian Vice Presidents over the period 1970 to 2020 is given in the final chapter of this book.

7 THE GENESIS OF THE AUSTRALIAN GEOMECHANICS SOCIETY

In Australia there was a relatively small professional population which had overlapping interests in civil and mining engineering and in soil and rock mechanics. The conviction developed that geomechanics learned society interests would be best served by one body. Consequently, at a meeting in Sydney in 1970, it was decided to form the Australian Geomechanics Society (AGS). This bold move was initiated by the National Committee of Soil Mechanics of the Institution of Engineers, Australia (established in 1953) with a call for a corresponding society in rock mechanics. I attended this inaugural meeting and was somewhat surprised that such an integration had not been undertaken earlier. The AGS was established under the joint auspices of the Institution of Engineers Australia and the Australasian Institute of Mining and Metallurgy. Professor Hugh Trollope became the first chairman of the new Society, and his forceful character was instrumental in its formation and acceptance by the parties involved.

In 1973 the AGS was expanded to include the third discipline of engineering geology and has remained substantially unchanged since that date.

Early chairmen of the AGS held office for a three-year period, but this was changed to two years in 1994. An interesting statistic is that, of the 22 chairmen of AGS to date, only 7 have been academics at the time of their chairmanship, while 15 were from industry. This is in contrast to societies in some other countries, where academics predominate and, in some cases, hold the chair for extended periods.

A complete table of chairmen of the Australian Geomechanics Society from 1970 to 2020 is provided in the final chapter of this book.

The integration of the three international societies within AGS reflects the close cooperation among the three sub-disciplines in geotechnical practice in Australia. While such cooperation also exists in some other countries, such as Canada and South Africa, it is by no means universal. A number of countries, for example in Europe, maintain sharp distinctions between soil mechanics and rock mechanics, and in particular, engineering geology.

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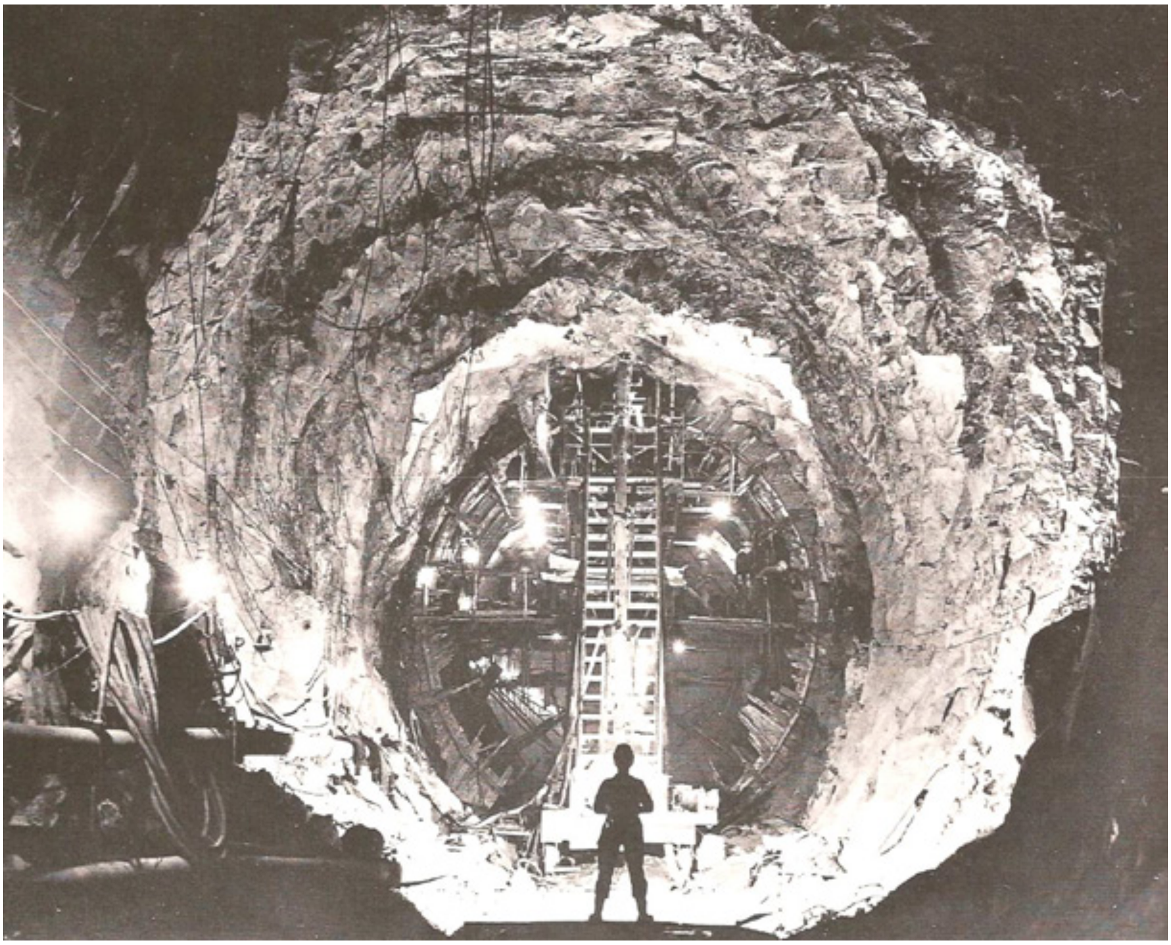
THE SNOWY MOUNTAINS HYDRO-ELECTRIC SCHEME



Snowy Mountains Authority iconic photograph of Tumut 2 tailwater tunnel with rockbolt support during concrete lining (1958-1961)

The Snowy Mountains Hydro-electric Scheme, with a capacity of 3800MW, is Australia's largest hydro scheme and accounts for around half of Australia's total hydroelectricity generation capacity. It is one of the most complex integrated water and hydroelectricity schemes in the world. The Scheme collects and stores the water that would normally flow east to the coast and diverts it through trans-mountain tunnels and power stations. The water is then released into the Murray and Murrumbidgee Rivers for irrigation. The Snowy Mountains Scheme comprises sixteen major dams, seven power stations (two of which are underground), a pumping station, 145km of inter-connected trans-mountain tunnels and 80km of aqueducts. In 1967 it was nominated by the American Society of Engineers as one of the engineering wonders of the world.

The Snowy Mountains Scheme was a plan for the nation, for national development. The prospect of diverting the Snowy waters inland had been considered from at least the 1880s, and very seriously in times of drought, but always led to argument between the colonies, and later the states, about the rights to the waters.

The Snowy Scheme commenced on 17 October 1949 at a ceremony on the banks of the Eucumbene River, Adaminaby. By 1955 the SMHEA was selling its first electricity. The total project was completed in 1974, not only on time and within the original estimate, but with much greater installed capacity and electricity output, and with much greater water storage.

This article was assembled by Tanya Kouzmin using extensive extracts from the publications by Brown (1999), Endersbee (1999) and Mills (2009).

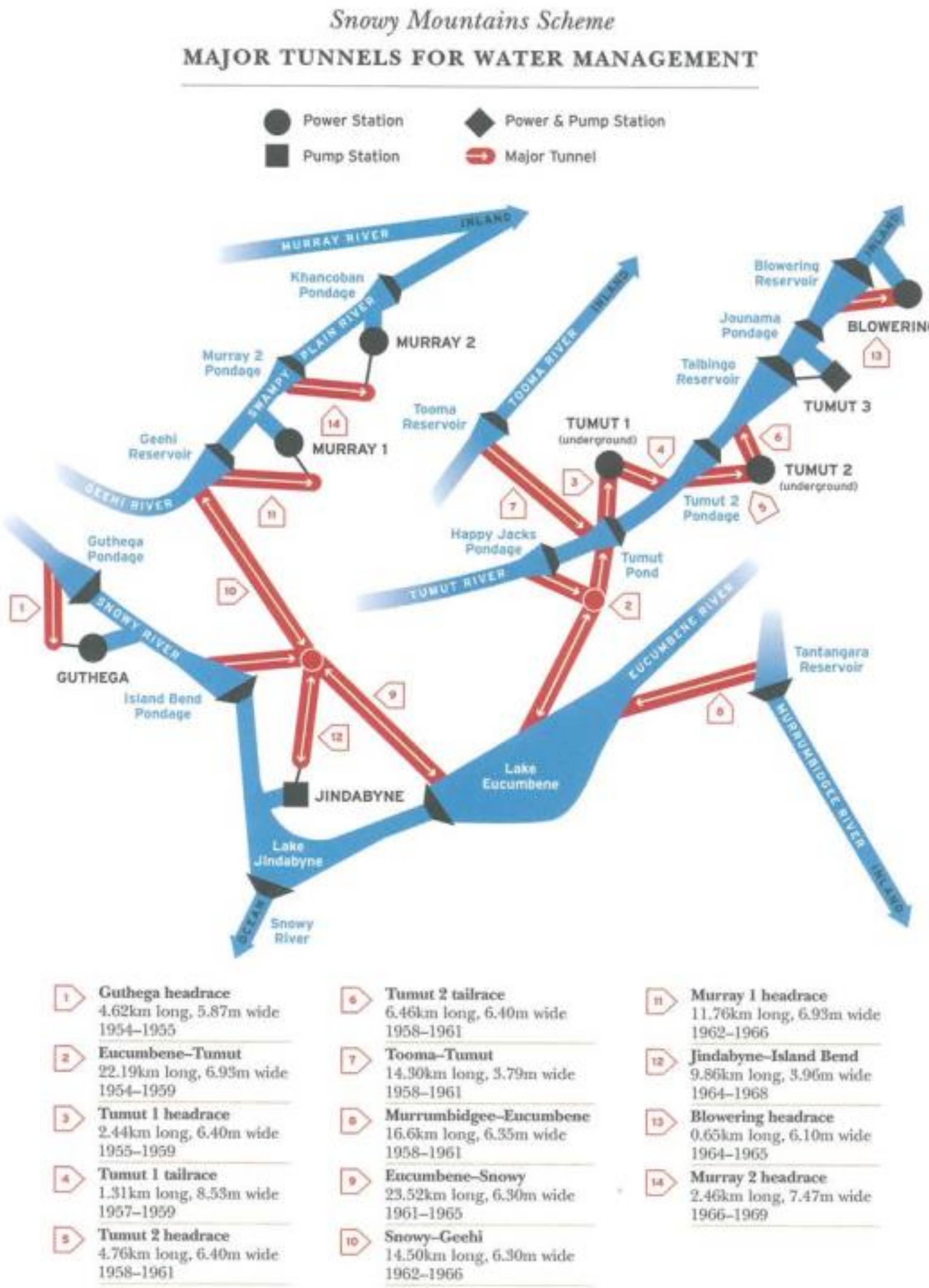


Figure 1: Schematic of the entire Snowy scheme (Mills, 2009)

FEASIBILITY PLANNING

The detailed work of investigations and evaluation of alternative proposals in 1946 was the task of E F Rowntree, Engineer for major Investigations at the Commonwealth Department of Works and Housing, together with a team of four other specialists. He assessed many possible alternative layouts. Every variation involved site inspections, estimation of river flows, and calculation of reservoir capacity and regulation of storages, outline designs and costs of dams, tunnels and power stations.

Figure 2: E F Rowntree DFC, taken towards the end of World War 1 (Endersbee, 1999)

LEGAL FRAMEWORK

Much of the credit for establishing the Snowy Authority goes to Nelson Lemmon. He was the Minister for Works and Housing in the Australian Government of Prime Minister Ben Chifley. A Western Australian, Lemmon was determined that the national interest would prevail, but understood that the Australian Constitution of 1900 did not assign any powers to the Commonwealth to build a project like the Snowy Scheme. The key objectives of the Snowy were to develop electricity and water resources, and these activities remained as residual powers of state governments.

Here is Lemmon's account of what some believe to be one of the most decisive moments in Australian history:

I went to Chifley...and I said, "There's only one way to handle this...Put the whole thing under the Defence Act ... and we'll be the boss." He said, "WHAT? Your name's Nelson Lemmon, not Ned Kelly - you can't do that?" So I said, "Why can't I?" "Well, he said, you tell me how you can!" So I said, "Listen! You had subs in the Harbour. The way we're building everything now, all they want is a decent cruiser and they could sneak through the guard and they could blow all your power stations out without an effort! You've got Bunnerong built on the water, you've got the big one at Wollongong built on the water ... they could blow all your damned electricity out in one night's shooting! Where'll you produce the arms, where'll your production be with all the power of New South Wales buggered?" Chif says, "You might get away with it ... If you can get Evatt to agree with it - and if there's a case he'll have to fight it in the High Court - if you can get Evatt to agree, I'll go all the way with you!"

Lemmon went to see H V Evatt, the Chifley Government's Attorney General. He knew that Evatt did not like Dedman, who was the Minister for Defence and Minister for Post-War Reconstruction. They were rivals. Lemmon told Evatt that Dedman had said they could not use the Defence Act. Evatt's support of Lemmon was immediate. Lemmon had his constitutional defender.

At the Premier's conference, Prime Minister Chifley advised the Premiers that the Commonwealth would proceed with the Scheme under the Defence powers. The Premiers were taken by surprise by this decision and simply noted the matter. They then proceeded to the next business. It was an immense gamble, but there was no other way. Lemmon was aware that the Commonwealth did not even have the power to compulsorily acquire land for the project, as that was a state function. The Commonwealth also did not have powers over diversion and use of water resources.

Chifley and Lemmon decided to move quickly towards construction to offset any possible legal challenges from the state governments, especially NSW. For this reason, the Snowy Act of 1949 concentrated on the hydro-electric aspect of the Scheme, but not the diversion of water inland for irrigation. The costs of the project were to be recovered from power charges, with the additional water for irrigation being provided at no cost to the benefiting states of NSW, Victoria and SA.

Figure 3: Hon. Nelson Lemmon, Minister for Works in the Commonwealth Government speaking at the official opening to mark the start of work on the Snowy Scheme, 17 October, 1949 (Endersbee, 1999)

SMHEA LEADERSHIP

The administrative form of the Snowy Authority was deliberately chosen to ensure that the construction of the project would proceed unimpeded by changes in the political environment.

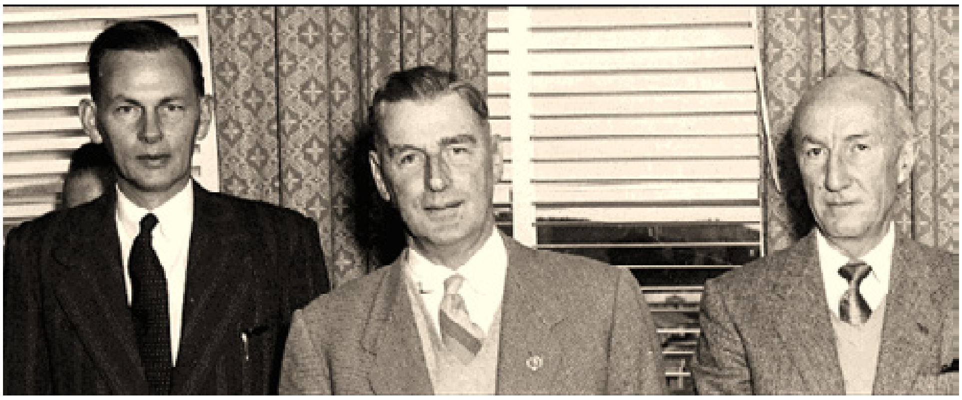


Figure 4: The top team. Commissioner William Hudson (centre) with Associate Commissioners Thomas A. Lang (left) and E. L. (Tony) Merigan (Endersbee, 1999)

The construction of the Scheme was seen as an engineering task, and Cabinet preferred the appointment of a single outstanding engineer to manage the Project, unimpeded by any Board or group of experts, or any representatives from state governments. They deliberately chose rule by one man.

The Authority was formally constituted as a single commissioner. Thus the Snowy Mountains Hydro-Electric Authority was, in law, one person. That was a fundamental departure from a normal ministerial department, although the concept of corporation sole had been quite effective in other public enterprises. In the case of the Snowy Scheme, it was outstandingly successful. There was no indication that the ultimate control of the project by a single commissioner was anything other than beneficial.

It was Nelson Lemmon who selected William Hudson as the Commissioner, and made a single recommendation to Cabinet. The record of the project shows that Hudson was an extraordinarily fine choice, and that the combination of capable leadership and unimpeded authority enabled the huge project to be built on time and within the estimate.

Hudson selected his two Associate Commissioners. Mr T A Lang, a young and distinguished civil engineer, and Commissioner of Irrigation and Water Supply in Queensland, and Mr E L Merigan, Electrical Engineer, State Electricity Commission of Victoria. It was the beginning of a great adventure. Australia had a population of only 8 million in 1949, and there were wide-ranging and critical post-war shortages of men and equipment.

CREATING COMPETENCE

There were very few engineers in Australia with experience in projects of that magnitude. The Authority had attracted an initial team of mostly young engineers, many with honours degrees and all with strong potential, but with no experience at all in hydro-electric engineering or major projects. The Authority decided to obtain overseas assistance in the preparation of designs and specifications for certain of the first major projects, and also to train the young engineers to a level whereby the Authority could complete the remainder of the Scheme from its own resources.

At that time many engineers around the world had been inspired by the achievements of the American civil engineers in the imaginative public works they built during the thirties, which included many big projects by the U.S. Bureau of Reclamation such as Hoover Dam, and the Central Valley Project in California. The Snowy Authority decided to seek assistance in the United States for the initial group of major projects. This prospect was examined in America by Associate Commissioner T. A. Lang. He proposed an agreement between the Commonwealth of Australia and the United States of America whereby the Bureau of Reclamation would undertake the preparation of designs and specifications for certain tunnel projects and dams, and provide training and experience for a number of Snowy engineers.

At the beginning of 1952, twelve Snowy engineers began work with the Bureau, studying their practices in design and construction of dams and tunnels. Eventually, over 100 young engineers benefited from the program. Lance Endersbee was in the first group of 12 engineers. His assignment from the Snowy was the study of the design of tunnels and underground structures. The Bureau of Reclamation promptly set him to work in the Denver offices on the actual designs for the Eucumbene-Tumut trans-mountain diversion tunnel, the associated regulating structures, and the Junction Intake Shaft.

The happy association with the Bureau of Reclamation was undoubtedly of tremendous benefit to the Authority, and to Australia. The concept of such detailed co-operation with an agency of another government, and the consequent inter-governmental agreement, was an act of much foresight and a credit to all concerned.

Within a few short years of the Authority being formed, the young engineers had matured into a capable, confident and united engineering team.

KEY GEOTECHNICAL PERSONNEL

DAN MOYE Chief Engineering Geologist from 1949 to 1967

A most capable engineering geologist and highly respected leader of his team. A plaque on Tumut Pond Dam is dedicated to his memory, and records that by his team's work they established the profession of engineering geology in Australia.

DAVID STAPLEDON Engineering geologist Tumut 2

David Stapledon was a pioneer on-site geologist for the second power station underground, Tumut 2. He wrote his Masters of Science thesis in 1962 based on his work in Tumut 2, which was of similar size to Tumut 1.

AUBREY HOSKING Soils Engineer

Aubrey Hosking was a soil mechanics expert and ran the SMA soil mechanics laboratory for many years. He was instrumental in establishing good understanding with many contractors' resident engineers to ensure that best practice was understood and adhered to.

LANCE ENDERSBEE Tunnelling Engineer

In 1952 Lance Endersbee was in the first batch of twelve young engineers sent to the US Bureau of Reclamation under a year long training plan instituted by Mr. Lang. Mr Endersbee played a leading role in the design research requirement for rock bolts on all jobs.

KENNETH SHARP Engineering geologist upper Tumut region

Following a 40 tonne rock fall in Tumut 1, both David Stapledon and Ken Sharp went on an overseas tour, looking specifically at rock bolt expansion shell anchorages that were on the market.

Others who made important contributions and successful careers in rock mechanics from their association with the Snowy Mountains Scheme included: J C Jaeger, C C Wood, E A Rudd, D Labefer, G Worotnicki, L G Alexander, and Tom Bowling.

DESIGN OF THE EUCUMBENE-TUMUT TUNNEL

When the Authority started work in 1949, little was known about the likely rock conditions for the long lengths of the several tunnels proposed in the Scheme.

This led to extensive site investigations, but even so, these could only provide limited data on the rock conditions at tunnel depths of over 300m . Thus the design of the tunnel, and the contract specifications and estimated quantities, had to provide for a variety of rock conditions that were known with little certainty. The uncertainties about the level of support required for construction purposes also applied to the quality of the rock to support the lining of the tunnel as a pressure tunnel.

The design provided for heavy steel reinforcing in the concrete lining adjacent to the gate shafts at each end of the tunnel, where the hydraulic pressure differential on either side of the tunnel closure gates reached a maximum of 105m head (at Tumut Gate Shaft). This made it a major reinforced concrete pressure tunnel by world standards.

Provision for construction support included:

- Arch steel supports and timber lagging,
- Arch steel supports, timber lagging and invert struts to cope with squeezing ground,
- Support by rock bolts of the slot and wedge type,
- Unsupported rock.

After the contract was awarded and as excavation of the tunnel proceeded, it was possible to review the design of the tunnel in relation to the actual rock conditions.

The Contractor was able to excavate the tunnel by drill and blast excavation to a fairly smooth bore even while achieving world record rates of construction. The soundness of the rock and the smooth excavation enabled much of the tunnel to be left unlined.

The quality of the rock near the portals and the two gate shafts was generally better than anticipated. It was evident that the rock support could carry much of the high hydraulic pressure in the tunnel near the gate shafts. This enabled a major reduction in the amount of reinforcement steel required. The excavation of the tunnel revealed sound massive rock for kilometre after kilometre in the deep underground sections of the 22.5 km long tunnel.

Figure 5: Eucumbene-Tumut tunnel during excavation (Endersbee, 1999)

The sound rock and the smooth bore offered the opportunity to omit the concrete lining over these sections, provided that the hydraulic properties were acceptable. Photographic profiles of the tunnel bore were used to estimate the equivalent hydraulic roughness, and this work indicated that the larger unlined sections would not cause significantly greater head loss than the smaller concrete lined sections. The savings in cost and time from omission of the concrete lining over long lengths of the tunnel were substantial.

TUMUT 1 AND TUMUT 2 POWER STATIONS

Possible sites for the underground power stations were investigated using air-photo interpretation, surface geological mapping and diamond drilling. Electrical resistivity logging and seismic refraction surveys were also used in site investigations for other structures in the Scheme. In the case of Tumut 1, four diamond drill holes ranging from 300 to 600m in length were first drilled from the surface into the rock at the proposed power station site. As the surface drilling indicated favourable conditions at the proposed site, an exploratory tunnel was driven to confirm and augment the data obtained from the surface drill holes and to enable direct examination of the rock in which the excavations would be made.

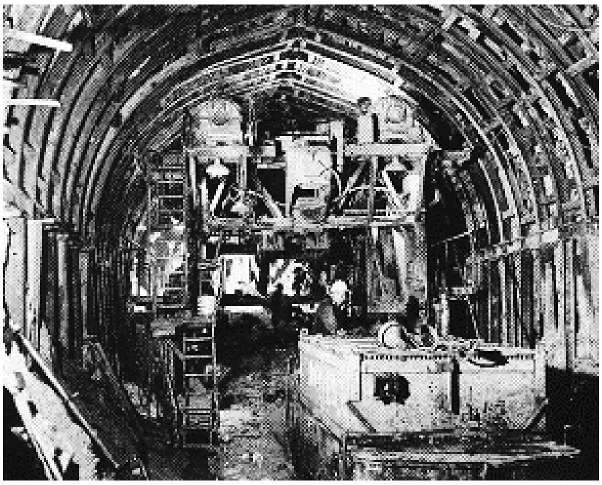


Figure 6: Eucumbene-Tumut tunnel in ground requiring steel arch supports (Endersbee, 1999)

From a chamber located at the end of the exploratory tunnel, six diamond drill holes with a total length of 420m, were drilled across the proposed excavations for the machine and transformer halls and draft tubes.

The core logs produced for diamond drill holes on the Snowy Scheme contain the same essential features as modern core logs although the details differ. The main rock mass classification scheme available at the time of the investigations for Tumut 1 and 2 was Terzaghi's scheme for estimating loads on tunnel supports. The concept of Rock Quality Designation (RQD) was not introduced until about 1963. The NGI Q system and Bieniawski's Rock Mass Rating (RMR) were not developed until the early 1970s. A simple rock classification scheme was developed for use on the Snowy and correlated with the support typically used in the underground works. Weathering of the essentially granitic rock masses at these and other sites was a major issue on the Snowy Scheme

Chief geologist Dan Moye made a major and lasting contribution to engineering geology by developing a weathering classification scheme for granitic rocks. Water pressure testing was also carried out in diamond drill holes from an early stage in the site investigation process to assess rock mass tightness and possible water loss from tunnels

An especially important feature of the site investigation work carried out in rock on the Snowy Scheme was the attention paid to high quality diamond drilling and core recovery. The desirability of core orientation was recognised but was not then able to be achieved.

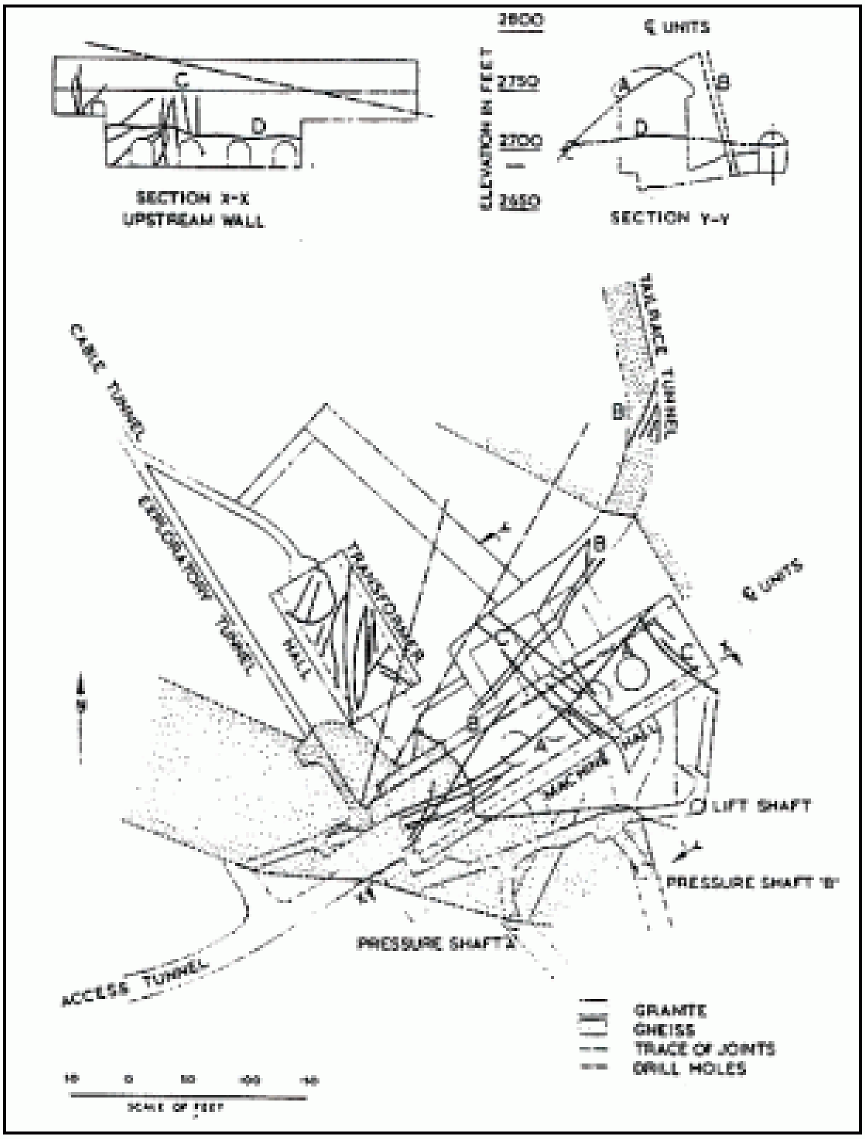


Figure 7: The geology and general arrangement of the Tumut 1 Power Station (Pinkerton et al., 1961)

The importance of jointing and faulting was well recognised and was taken into account in the design, including the orientations of the major underground excavations. It appears that not all discontinuities encountered in a borehole or along an exposure were mapped and plotted on a stereographic projection as they are today, and were in the latter stages of the Snowy Scheme. However, the major joint sets and their orientations were identified (but not expressed in the now standard dip and dip direction terms) and presented as rosette diagrams (Figure 8). The conditions of joint surfaces were also recorded.

Laboratory tests were carried out on unjointed cores of the rocks to measure their uniaxial compressive and tensile strengths, Young's moduli and Poisson's ratios.

While Tumut 1 and Tumut 2 were not the largest or the deepest underground power station excavations in the world at the time of their construction, they were of significant size by the then world standards. However, it is not their size but the contributions made to the development of underground rock engineering during their investigation, design and construction that makes them worthy of detailed study more than 40 years later.

The Tumut 1 power station and the associated works were constructed in the period 1955-59 with the excavation of the power station chamber taking place in 1956-57. Designs for Tumut 1 underground power station were carried out entirely by the Snowy design engineers. The successful contractor for the power station was a French group headed by Etudes et Enterprises.

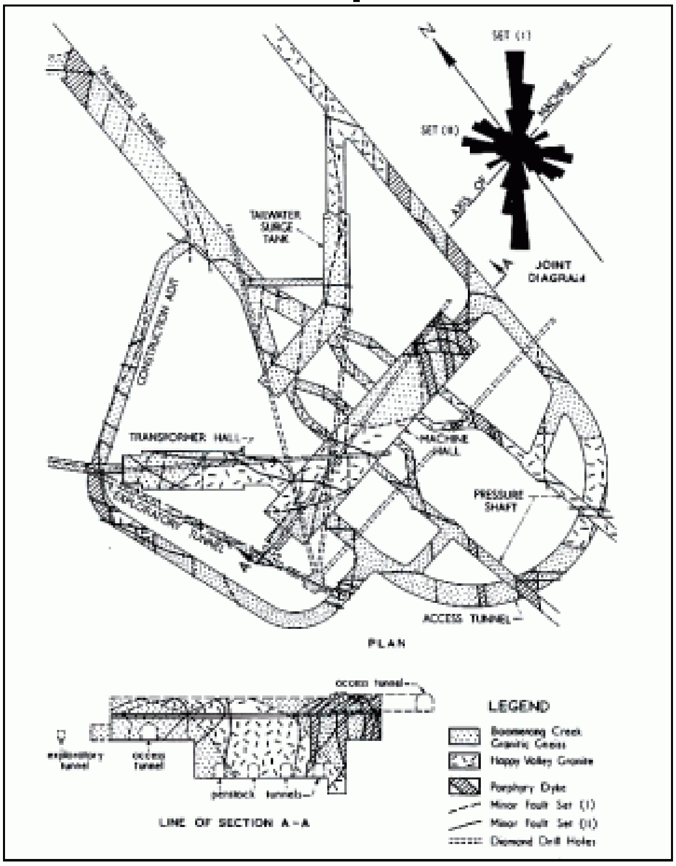


Figure 8: Geology, joint rosette and general arrangement for the Tumut 2 power station (Pinkerton & Gibson, 1964)

A critical question was the stability of the roof and walls of the underground caverns during construction and thereafter, and the associated requirements for temporary and permanent support. Photo-elastic studies were conducted on the probable distribution of stresses in the rock in the proposed arrangement.

Model stress investigations using the photo-elastic method were conducted to determine the probable distribution of stresses in the rock around the proposed cavern. The layout was accordingly amended to avoid adverse stress interactions between the machine hall and the transformer hall. During construction, the excavation of a pilot tunnel through the machine hall revealed superior quality granite at one end, and it was decided to relocate the machine hall by moving it into the better rock.

The flat jack method was used to determine stresses in the rock in the walls of an exploratory adit. The cross sectional shape of the adit was reproduced in a photo-elastic model from which the stress concentration factors at the flat jack sites could be determined. Using these factors and the measured stresses at the flat jack sites, the pre-existing stresses in the rock, that is prior to excavation, could be determined. The innovative flat jack test had been developed in France in the 1950s and had been improved and refined by the SMHEA's Laurie Alexander.

Large flows of groundwater were encountered in the exploratory excavations. As the excavations progressed it was noted that practically the entire groundwater flow came from relatively few open fissures, with the remainder of the rock mass being practically impervious, with tight joints. Flows reduced in time. It was decided to preserve the free draining properties of the rock in the design of the station.

This eliminated any need for grouting of the rock or the use of impervious linings. The roof of the machine hall and transformer hall was designed to be free-draining, with reinforced concrete arch ribs against the rock and a suspended waterproof ceiling.

Figure 9 shows in the background the steel support system that was installed by the Contractor in addition to the specified rock bolts. The full width of the excavation standing supported by rock bolts alone is shown in the foreground. When the steel support system was removed to permit construction of the permanent concrete arch ribs, there was no detectable movement of the rock.

Figure 9: Tumut 1 power station during excavation of the roof section of the machine hall cavern (Endersbee, 1999)

ROCK BOLTING

The discovery that large diameter tunnels and caverns, and tunnels passing through highly fractured rock zones, can be made stable through simple and economic means was a significant achievement in Australia's engineering heritage. In the late 1950s SMA engineers and scientists devised a method to prevent large diameter tunnels from collapse through the use of patterned rock bolting, with bolt placement designed according to the rock structure.

The Rock Bolt itself was simply a rod of mild steel up to about 25mm diameter that could be anchored in the rock with a steel wedge in a slot cut in the end of the bolt. By driving the bolt into the rock hole the wedge expanded the end of the bolt to form an anchor. The bolt was then stressed by tightening a nut on the threaded external end of the bolt through a plate washer bearing on the external rock face. The bolt was tightened with a torque wrench to a load somewhat less than steel yield. When used with other bolts, in a pattern according to the rock structure encountered, they could lock the movement of the exposed rock to almost eliminate any tendency for tunnel collapse. But it had to be done within a few hours of the tunnel's creation for best effect.

Brown (1999) notes that although it had been used on a few projects in North America and France in the early 1950s, at the time of the design and construction of the early tunnels on the Snowy Scheme, rock bolting was not an established method of rock support in civil engineering either in Australia or elsewhere.

On the Snowy Scheme, some rock bolts were used in the Guthega Project excavated in the period 1952-54, but the first major use of rock bolts in the Authority's works was in Tumut 1 power station excavated in 1956-57. This represented quite a major departure from the then traditional steel set and concrete support.

In the early to mid-1950s, it was generally held that the purpose of rock bolts was to pin surface rock (either individual blocks or bedded strata as encountered in underground coal mining) to more stable rock some distance from the surface of the excavation. However model tests had been carried out which suggested that a rock mass consisting entirely of blocks or fragments could be held stable by systematic bolting. The team of investigation and design engineers working on the Snowy with the Assistant Commissioner, T A Lang, as the driving force proved, developed and applied this concept with remarkable effect. Indeed, it has been suggested that the development and use of rock bolting for permanent support of underground excavations was probably the most significant engineering development made on the Snowy Scheme.

There was an evident need for a better scientific understanding of the mechanics of rock bolting. Associate Commissioner Lang initiated a series of studies directed to these purposes. The studies included:

- mathematical models of rock bolts acting in jointed rock, and physical conditions for sliding and stability;

- photo-elastic studies of the distribution of stresses around openings in jointed rock, using gelatin models to simulate self-weight in the rock mass;
- physical block models to simulate the pattern of joints in the rock mass, with model rock bolts providing support;
- photo-elastic studies of the effects of length and spacing of rock bolts on the pattern of stress in the rock created by bolts;
- installation and pull-out tests on actual rock bolts to study setting torque, anchorage behaviour, and bolt strength;
- crushed rock models, with crushed rock being considered as an extreme case of highly jointed rock.

The crushed rock models were the most convincing way of demonstrating the effectiveness of rock bolts in providing support in highly jointed rock.

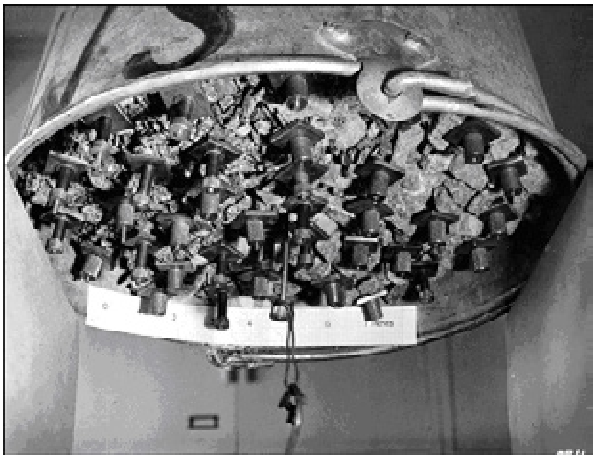


Figure 10: The upturned bucket demonstration (Endersbee, 1999)

There was a need to explain to workmen, whose lives depended on sound rock support in underground excavations, the way rock bolts worked in supporting jointed rock. In this demonstration, model rock bolts were placed in a bucket, crushed rock was then placed around the bolts, and the bolts then tightened on to the crushed rock. The bucket would then be held upside down, and the crushed rock would be seen to remain in the bucket.

That was surprising. While still upside down, a heavy weight would then be applied to a middle rock bolt, and still the crushed rock remained in place. That was amazing. The workmen would then be reminded that all this was possible because there was a pattern of rock bolts, and that the bolts worked together Eventually a heavier load would cause the contents to cascade onto the floor, at which stage some older miner would growl that he knew it wouldn't work.

Studies by Aubrey Hosking showed that open graded crushed rock could be stabilised by rock bolts so that it could span over an opening and carry a substantial load. The rock bolts could create an effective structural member out of otherwise loose rock. Only relatively flimsy mesh support was needed to cope with surface looseness.

At Tumut 1 power station, rock bolts were used as construction support. It was now evident that rock bolts could be used as permanent support of the rock if they could be protected from corrosion.

Further rock bolting refinements were researched and by 1959 the final step for permanency was achieved. At the same time the concept was being picked up in the tunnel construction industry worldwide. Now 70 years later the standard method and hardware remains essentially the same as those developed by SMA personnel. It is for these reasons that Engineers Australia awarded the rock bolting development site in Lambie Gorge in Cooma, a National Heritage Landmark, the highest level of engineering heritage recognition.

Consideration was given to the use of metals other than steel. Comparative costs indicated that the best solution was to use a tensioned steel bolt grouted in place with cement grout. The grout would fill any open joints, and provide an alkaline environment to protect the bolt shank and anchor from corrosion.

The solution finally adopted on later projects was to use 25mm nominal diameter steel bolts with a central hole and deformed shank, with expansion shell anchorages rather than the less reliable slot and wedge anchors. The central hole acts as a de-aeration vent, with the grout being injected through a short tube through the bearing plate and drill hole seal into the space between the bolt and the rock wall of the hole.

By the end of the first decade on the Snowy, forward bolting was being used in tunnels, thereby avoiding the use of steel sets in many cases where they would have otherwise been used. The Snowy had led a major change in world tunnelling practice in hard rock.

LINING DESIGN AND STRESS ANALYSIS

At the time of the design of the major underground excavations on the Snowy Scheme, there existed a number of closed-form solutions for the stresses around excavations with simple shapes (eg Terzaghi & Richart, 1952). In Europe, methods of calculation for tunnel support and lining design had been developed (eg Szechy, 1973). There were no digital computers or numerical methods of the types that are now used in carrying out complex stress analyses of underground excavations.

The design stress analyses for the Tumut 1 and Tumut 2 power stations were carried out using the photo-elastic method. This work was carried out by George Worotnicki and required considerable ingenuity and skill. The state-of-the-art at the time was to use fully concrete-lined arched roofs with load bearing ribs. In the case of the underground power stations on the Snowy, it was planned to use systematic rock bolting in a fairly close pattern so as to tie the rock together at the joints, thus maintaining structural continuity of the rock immediately surrounding the excavations. The roof of Tumut 1 was supported by concrete ribs designed to support a nominal load of 12 ft (3.66 m) of loosened rock. In the design, it was assumed that the roof section would be excavated first and that the concrete ribs would be placed before the excavation was carried further down.

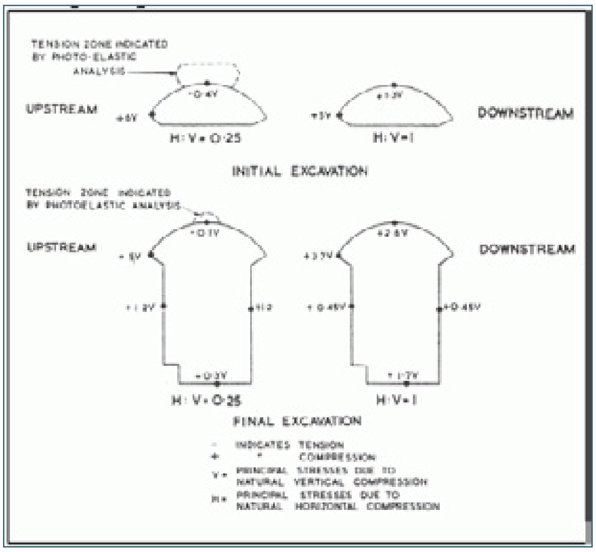


Figure 11: Results of photo-elastic stress analysis (Pinkerton et al., 1961)

The results of the two-dimensional photo-elastic stress analysis for this stage, assuming a horizontal to vertical in-situ stress ratio of 0.25, are shown in the upper left-hand part of Figure 11. These results indicated that the central part of the roof would be in tension and that high compressive stresses would exist at the abutments. These studies also showed, as illustrated in the lower left-hand side diagram of Figure 11, that the value of the roof tension would decrease and that tension would develop in the rock walls immediately below the roof abutments as excavation proceeded downwards. In the remaining sections of the walls, the compressive stresses indicated by the photo-elastic analyses were considerably less than the compressive strength of the rock as determined in the laboratory. The designers concluded that, if the rock in the roof was stable following the initial excavation, no troubles should be encountered as the excavation progressed further.

MONITORING AND RETROSPECTIVE ANALYSIS

The excavations were thoroughly monitored during and after construction. Measurements made in the roof ribs showed that the compressive stress in the concrete increased very sharply as the excavation proceeded down from the roof abutments. It was recognised that the likely explanation of this was the existence of much higher horizontal stresses than those assumed on the basis of classical "theory". It was decided immediately to make stress measurements in the power station excavations using the flat-jack method.

Sites for the flat-jack tests were carefully selected at locations where fairly massive rock occurred. It was recognised that in order to determine from these results the stresses in the rock mass before excavation, it was necessary to establish the local stress concentration factors taking account of the shapes of the excavations in which the measurements were made. This was done by photo-elastic stress analysis and the final results showed an average equivalent vertical stress of approximately 12.4MPa and a horizontal stress transverse to the machine hall of 10.3MPa.

Further photo-elastic stress analyses were then carried out for Tumut 1 with a ratio of horizontal to vertical in situ stress of one. The results are shown on the right hand side of Figure 11. The predictions made using these models showed very good correlation with the monitoring data.

The design investigations underway for Tumut 2 made use of this experience in Tumut 1. Flat-jack tests were carried out, as a result of which a ratio of horizontal to vertical stress of 1.2 was adopted in the design. Based on the experience of Tumut 1, the roof abutment design was modified for Tumut 2. The stresses around the periphery of the excavation calculated from the photo-elastic stress analyses showed remarkably good agreement with those measured during and after excavation.

Although the techniques used in these studies may seem primitive in today's computer age, at the time they were at the forefront of developments in the field and demonstrated engineering skills of a high order. There were no more sophisticated and effective stress analyses being carried out at the time (or for a long time afterwards) than the photo-elastic analyses of G Worotnicki on the Snowy. The skills of L G Alexander in carrying out and interpreting early flat-jack and monitoring measurements were also of a very high standard.

On the basis of these experiments and through field experience, the Snowy team developed an understanding of the way in which systematic rock bolting in a significantly jointed rock mass forms a self-supporting compression zone within the rock mass. This effect is illustrated in Figure 12.

In addition, a set of design rules was developed for pattern rock bolting which related bolt length and spacing to block size. These rules have represented best practice or many years. Subsequently Lang published pioneering analyses of the ways in which single rock bolts may prevent slip on single joints and single blocks of rock may be stabilised.

Figure 13 shows the means of the surface displacements measured on several survey lines on either wall of the machine hall excavation. Near mid-height on either wall 40ft (12.2m) below the abutments, the mean deflections were 0.5in (13mm) on the upstream wall and 0.7in (18mm) on the downstream wall. The predicted values shown in Figure 13 are consistent with a modulus of elasticity of the rock mass of 15GPa.

The monitoring techniques used reflected and advanced the then state-of-the-art. In Tumut 2, rod extensometers comprising 4ft (1.22m) to 14ft (4.27m) long rock bolts were used to measure the normal wall dilation. It was concluded that, in addition to elastic expansion of the rock arising from stress relief, there was opening of joints in the rock between depths of 8 ft (2.44 m) and 12 ft (3.66 m) Possible types of block movement identified as being associated with joints are shown in Figure 14.

This approach to monitoring rock mass performance and interpreting the results obtained was advanced at the time and differs little from the approach likely to be used today although the required instruments are now available commercially and are more sophisticated than those developed by the Snowy engineers.

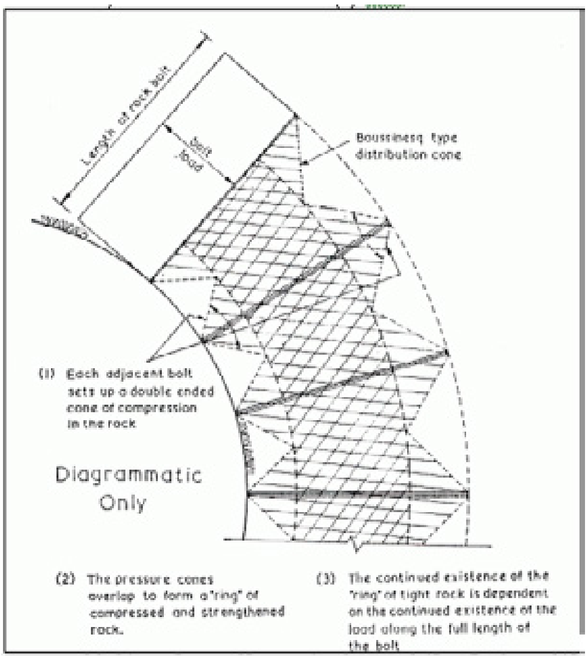


Figure 12: Action of pattern rock bolting to form a self-supporting ring or arch (Pender et al., 1963)

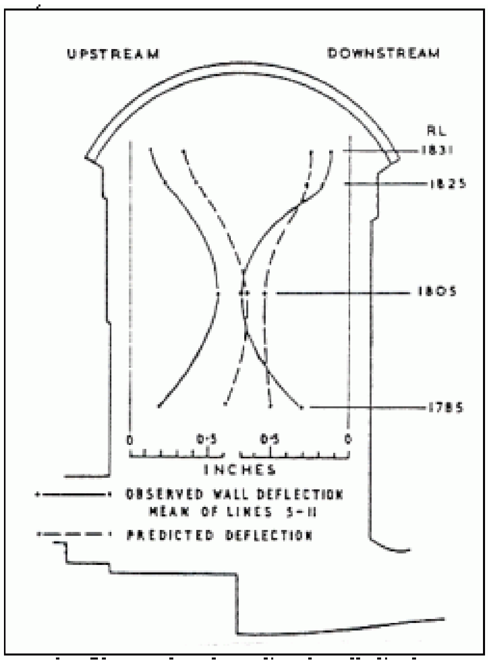


Figure 13: Observed and predicted wall displacements, Tumut 2 Power Station (Alexander et al., 1961)

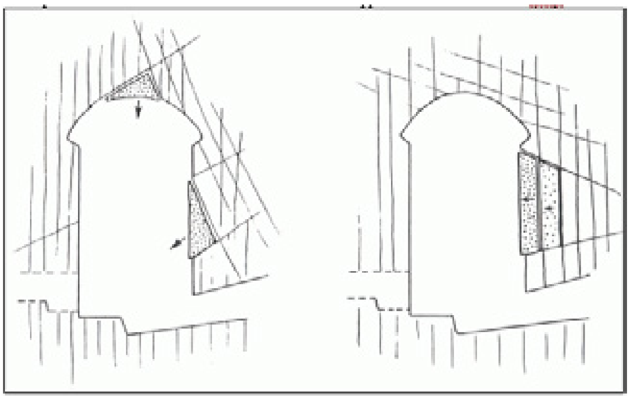


Figure 14: Possible failure mechanisms in jointed rock (Stapledon, 1961)

THE SNOWY'S ROCK MECHANICS LEGACY

Brown (1999) concluded that the work carried out on the Snowy Mountains Hydro-Electric Scheme advanced the then state-of-the-art in rock mechanics and rock engineering for large tunnels and underground excavations. High level expertise was developed from the low levels pre-existing in Australia in almost all areas of underground excavation engineering in rock. This included site investigation and rock mass characterisation, design analysis using the photo-elastic method of stress analysis, the theory and practice of rock bolting and rock mass performance monitoring. This expertise led not only to the successful construction of the underground excavations of the Snowy Scheme but advanced the state-of-the-art internationally.

The high standard of rock mechanics work carried out on the Snowy Scheme was emulated in the hydroelectric developments undertaken in the latter part of the Snowy construction period by the Hydro-Electric Commission of Tasmania. The Australian mining industry soon took advantage of the rapid development of rock mechanics expertise that took place in the 1950s and 1960s. In the 1960s a number of Australian mining companies used the expertise built up on the Snowy Scheme for advice on specific problems. At the same time, Mount Isa Mines established what was, for some time, one of the strongest applied rock mechanics groups working on a particular mining operation anywhere in the world. These and other developments were aided greatly by the fundamental and applied rock mechanics research, and the training of students in the field, carried out by Professor J C Jaeger at the Australian National University from the late 1950s, by Professor D H Trollope at the then University College of Townsville from the mid-1960s, and soon after by the CSIRO which L G Alexander and G Worotnicki joined from the SMHEA.

The work carried out on the Snowy stands as a high point in the history of the development of rock mechanics and of underground rock engineering. It provided the impetus for the many Australian contributions made to geomechanics generally, and to rock mechanics and its application in the subsequent two decades.

ACKNOWLEDGEMENTS

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- for reviewing this article: Ted Brown, Tom Bowling, Harry Poulos;
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- for proof reading: Rowenna Lagden and Nina Levy.

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ADELAIDE'S BUILDING FOUNDATIONS RESEARCH LABORATORY

JOHN WOODBURN

Geotechnical engineer with unsaturated clays and broad scale terrain evaluation being fields of special interest. Commenced working with the Department of Works in Adelaide in 1964, then moved to CSIRO, Soil Mechanics Section. Worked under Dr Gordon Aitchison on a rational design procedure for domestic footings needed to address the problem of cracking in houses. Moved to Coffey and Hollingsworth in Sydney in 1969 where the realities of consulting engineering were brought home. Back to Adelaide in 1971 with David Stapledon to open the office for Coffeys. Opened the office of Woodburn Associates in the early 1970's which became Woodburn Fitzhardinge in 1985 and Golder Associates in the early 1990s. Then reverted to a sole practitioner and remains so.

Fifty years ago the footing design for a house in Adelaide was a relatively simple matter. A pit was dug on your block of land to a depth of about 4 feet (1.2m) and a geologist from the Department of Mines would come out to identify the soil type using their soil classification system. A recommendation would then be made on the size and reinforcement required for either a strip footing or pier and beam footing for support of the external and internal walls. Floors were usually of timber supported on these footings with brick internal "dwarf" walls with no footings, between them. Concrete floors were rare and when specified were later poured between the walls after filling between the footings with sand.

Houses in Adelaide at the time were mainly of solid brick construction with double brick, external cavity walls and single brick on the flat and later on edge (to save bricks) for the internal walls. Ceiling heights were either 9 or 10 feet (2.7 or 3.0m) and brick was continuous over windows and doorways with no control joints. Consequently the houses were extremely brittle and could not tolerate much footing movement. Adelaide with its large areas of expansive soils was renowned as the place where houses generally cracked.

It had been established during earlier work published by the Department of Mines (The Soils and Geology of Adelaide and Suburbs, Bulletin 32, 1954) that the magnitude of soil movement due to changes in the moisture content of the local soils was related to the soil type which varied from stable sand to highly reactive clay. Appendix B in the Bulletin contained recommendations for footings linked to the range of soil types found in the metropolitan area. The most reactive of the clays was the Black Earth (Soil Type BE1), known locally as Bay of Biscay soil due to the undulating nature of the ground surface. Footings specified for this soil consisted of a system of piers to at least 7 feet (2.1m), considered to be the zone of seasonal influence. Beams had to be cast with at least a 3 inch (75mm) gap underneath them to allow for the seasonal movement.

Bulletin 32 was the outcome of work carried out in collaboration by the South Australian Department of Mines and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Soils. It was natural therefore that in the 1960's when it was recognized that further research was required as house cracking had continued despite the recommendations in the Bulletin, that another joint program of soil identification and classification in terms of engineering properties should be inaugurated by the Soil Mechanics Section of CSIRO (later the Division of Applied Geomechanics) and the South Australian Department of Mines. The conclusions in Bulletin 32 that the reactive (volume change) properties of a soil were related to the pedological soil type were considered still valid and resulted in an extensive sampling and soil mapping program with Dr J. K. Taylor, the retired Chief of the Division of Soils identifying sites and Dr G. D. Aitchison, Head of the Soil Mechanics Section, taking responsibility for the laboratory testing and quantification of the engineering properties.

Soon after this work commenced and after completing a master's thesis on "The Consolidation and Suction Properties of Adelaide Pleistocene Clay" (1967) at The University of Adelaide I joined CSIRO to manage a new laboratory set up to carry out the testing for the program. The laboratory was in the city on North Terrace, close to the Department of Mines and was given the grand title of The Building Foundations Research Laboratory.

SAMPLING AND TESTING

The Department of Mines sampling program gave us almost continuous core in 100mm x 450mm long sealed tubes from the surface to about 3 metres. The soils were logged by a Department geologist with emphasis placed on identification of the various soil horizons. There were up to 5 or 6 of these with the topsoil horizons: (A1 and A2;, the reactive clay horizons (B horizons: B1, B2 and BCa if there was a calcareous layer present); and the parent material C horizon which could be weathered rock (denoting a residual profile) or transported material.

Sometimes these horizons were easily identified with distinct boundaries but were occasionally classed as gradational (particularly when on weathered bedrock). There was great excitement when the geologist/pedologist identified a two storey profile with the more modern surface profile overlying an older soil identified by the presence of relict A horizons. These profiles were generally located in the estuarine zones north of the city or in areas of deep colluvium on the footslopes of the Mt Lofty Ranges.

After the soil logs were given to the laboratory the cores were subsampled and, where appropriate, testing for Atterberg Limits, swelling pressure and soil suction carried out. At that time, and particularly in the United States, much emphasis was placed on the Plasticity Index of the clay horizons and an empirical relationship between PI and the expansive nature of the soil had developed. This relationship was mainly based on historical data of the behaviour of buildings and pavements on what were termed expansive clay soils.

Work on the swelling pressure of unsaturated soils had been carried out for a number of years in the United Kingdom and South Africa where a double oedometer test had been developed for the assessment of potential ground movement. There were a number of versions of the swelling pressure test but the procedure mainly used at CSIRO consisted of flooding a sample in an oedometer cell and loading it to keep the volume constant. Initial and final moisture contents were recorded as well as the pressure required to keep the sample at constant volume. In Adelaide we also had the benefit of psychrometric equipment which allowed the initial soil suction to be measured.

The Soil Mechanics Section's head office was at Syndal in Victoria where Dr Brian Richards, another Adelaide geotechnical engineer was carrying out extensive work on suction profiles under pavements throughout Australia. This work was published by Butterworths as a symposium in print "Moisture Equilibria and Moisture Changes in Soils beneath Covered Areas" in 1965. For suction measurements Brian had developed the thermistor psychrometer which was the electronic equivalent of the wet and dry bulb thermometer used for measuring the relative humidity of the air in equilibrium with a small soil sample. As a relative humidity in excess of about 98% needed to be measured (i.e. soil suctions below about pF4.5) a constant temperature environment was required. This meant all measurements had to be carried out in a constant temperature room with the probes inserted into a lagged water bath. This ensured that during the one hour needed for the test the temperature did not vary by more than about one hundredth of a degree centigrade.

THE SOIL MAPS

In parallel with this work and right through the 1970's and into the 1980's the Department of Mines produced soil maps of the Adelaide metropolitan area with the first Soil Association Map of the Adelaide Region published in 1972 at a scale of 1:50,000. This was followed by a more detailed set of 4 maps at a scale of 1:15,840 each with associated explanatory notes. These larger scale maps allowed the dominant soil types within each association to be more clearly defined.

By the time a revised version of the Soil Association map was produced in 1989 considerable work had been carried out on the identification of areas of deep, highly to extremely expansive clays underlying the surface soils of Adelaide. The presence of these clays was found to be widespread and led to the need for deeper investigation of soils on domestic sites. The need for identification of such soils on building sites is now noted in the Standard and affects the ultimate footing design.

THE VOLUME CHANGE CHARACTERISTIC ΔH/H

During my postgraduate work I had tracked the consolidation of remolded Pleistocene clay samples when subjected to either conventionally applied loads or suction pressures behind high air entry porous plates or, in some cases, a combination of both. This work led to the development in CSIRO's Adelaide laboratory of the membrane oedometer where even higher suctions could be induced in samples contained in a cell with an high air pressure. (A later modification of this cell allowed saline flushing water to be used below the membrane thus changing the solute suction in the soil sample as well as the matrix suction.)

We soon had a number of these cells working, establishing the volume change properties of the various soil types being mapped by the Department of Mines. This apparatus was unveiled at the Seventh International Conference of Soil Mechanics and Foundation Engineering at Mexico in 1969. The work allowed us to produce preliminary information on the volume change in terms of $\Delta h/h$ per 1.0pF suction change and some figures were given during an Adult Education series on Practical Aspects of Soil Mechanics at the University of Adelaide organized by Dr Maurice Arnold, the senior lecturer in Geomechanics, in 1972.

It was recognized that this test, although useful for establishing base line data for the volume change characteristic of "standard" soil types was lengthy and that a more simple, faster test was needed if testing was to become more routine as part of the approach for footing design.

Examination of the moisture characteristic curves (moisture content/soil suction) indicated how this could be done as the shrinkage curves always flattened out at a suction of about pF5.8 (the shrinkage limit). This indicated that soil samples could be left to air dry until no further volume change occurred. If the initial suction was known and the change in length measured, then the change in length per unit change in pF was all that was required to establish a volume change parameter. For the test 35mm diameter samples about 70mm long were monitored as they dried out. To make measurement easier drawing pins were pushed into the sample at each end. A more sophisticated method later evolved and became part of AS1289.

There was some discussion between Gordon and myself regarding the form and name of this volume change parameter. Gordon preferred the term Instability Index whereas I wanted something with volume change in the name. He won, he was the Chief!

TOWARDS A RATIONAL DESIGN PROCEDURE

Soon after I joined CSIRO Gordon Aitchison impressed on me the need for a more rational design procedure for footings for domestic buildings rather than the empirical one using soil types as the basis for footing sizes as outlined in Bulletin 32. It was realized that a volume change equation which included changes in soil suction was needed in order to assess the amount of soil movement which might occur under a footing during the lifetime of a structure and more particularly soon after construction.

As discussed in our Mexico conference paper, the use of the generalized effective stress equation $\sigma' = \sigma + X\ (\mu_a - \mu_w) - \mu_a$ for the quantitative prediction of volume changes and foundation behaviour was unlikely to lead to a satisfactory outcome for a number of reasons. What became obvious to us as engineers was that a much simpler but realistic approach was required. When we looked at the volume changes and surface movements caused by changes in both the applied load and suction components of the effective stress it led us to the conclusion that complete separation of their contributions was the path to follow. But first we had to establish a few more parameters.

THE SUCTION CHANGE, THE VOLUME CHANGE AND THE TOTAL MOVEMENT

The assessment of the equilibrium condition under a structure had been discussed by Brian Richards in the 1965 Butterworths' publication and, with the additional information that we had from further laboratory testing, we verified that an equilibrium suction between pF4.0 and pF4.1 was applicable for most parts of Adelaide. This also agreed with the Thornthwaite Moisture Index values using climate data for our area. Our measurements of many field profiles had also established what seemed to be the suction values for the wettest and driest condition and the depth below which the suction value was likely to remain constant regardless of changing surface environmental conditions. This study led to the selection for design of a variation of pF1.2 at the surface and a depth of between 2 and 3 metres below which suction changes were unlikely. (This was later increased after further investigations to 4 metres for the Standard).

With the Instability Index values we had for the various soil horizons in each soil type, calculation of the volume change (y_m) then became a simple matter. This was made easier using the nomograph shown below:

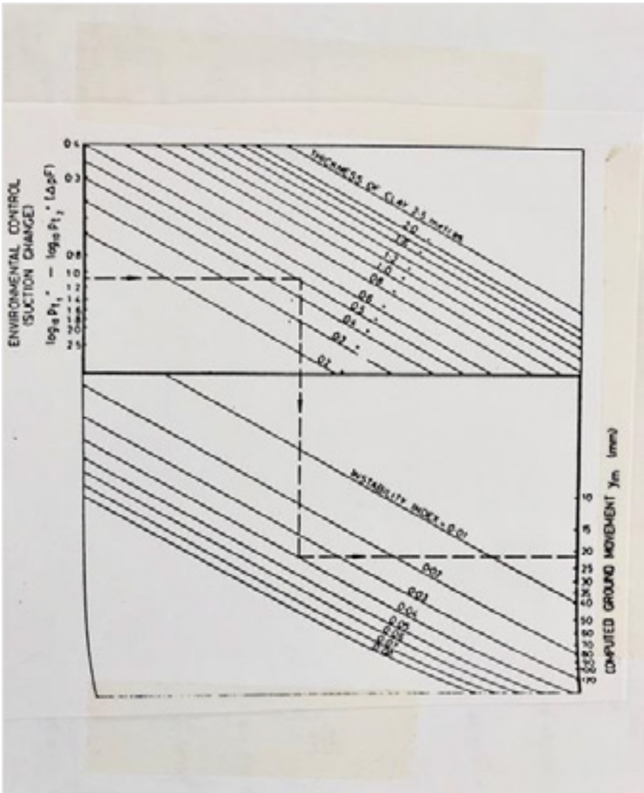

Figure 1: Nomograph for the computation of soil movement due to suction change

As can be seen at that time we were using the term "environmental control" to indicate the change in suction of a particular layer. Summation of the volume change in each layer immediately gave us a value for the predicted surface movement (y_s). These days it is all in the software which now thankfully includes rounding up the values rather than showing a heave calculation to points of a millimetre!

A DISTRACTION - THE ALLOWABLE DEFLECTION RATIO Δ/L

Perhaps more difficult than computing y_s was establishing the limit on deflections required to ensure that buildings did not crack or distort to an unacceptable level. There were some vague figures around for acceptable deflections but nothing that was particularly applicable to domestic buildings. An extensive literature search also revealed very little information.

Examination of the housing scene in Adelaide revealed that most houses were of solid brick construction although brick veneer, which was used extensively interstate, seemed to be on the ascendant with more timber becoming available from the pine forests in the south-east of the state. Hickinbotham Homes were also pioneering articulated brick construction (with Hosking, Fargher and Oborn as their consulting engineers) on raft footings which were being actively promoted by the Cement and Concrete Association. Also as luck would have it, the Civil Engineering Department of the University of Adelaide had recently constructed a number of brick walls which had been tested to destruction on their test bed by either hogging or sagging movements. Some of these walls were hard to crack, they had been too well built!

The information gained from all of these sources allowed us to divide houses into 5 categories each of which was described with photographs and allowable deflection ratios which varied from 1/200 for timber dwellings to 1/2000 for solid masonry. This classification was recognised during the Cracking of Houses Enquiry in 1980 and circulated throughout the building industry.

With very little change these values are still in use today and have been incorporated into AS2870. Following this work a leaflet describing the building types was published by CSIRO and many consulting engineers started to include this information with their footing reports so that clients would recognise their house type and the order of movements which might be expected.

More importantly Dr Paul Walsh of CSIRO Division of Building Research produced in 1986 a Guide to Home Owners on Foundation Maintenance and Footing Performance.

FOOTING DESIGN

We had decided early in the study that if possible, currently available mathematical models for the sizing of strip and raft footings would be used in the design procedure. Our work was to concentrate on the setting out of a rational procedure that was particularly applicable to house footings, the basic aim being to formalize the procedure and to reduce the possibility of excessive cracking. We did not want to repeat and/or modify much of the work already carried out on the modelling.

In the late 1960's there were two options for the design of a strip footing on an expansive soil. Both modelled a beam on an elastic foundation comprising a set of springs. The simplest of these was the Winkler foundation comprising a series of individual springs. A more complex arrangement was the coupled spring foundation in which the springs were joined together with another spring to form a truly elastic continuum. Dr Bob Lytton at College Station in the United States had developed the latter to produce a series of charts relating soil stiffness to loads and deflections. At the time of our examination of an appropriate approach to the design of strip footings Bob was on leave from College Station and spent some time with the Soil Mechanics Section in Victoria. It was his approach that was chosen as the basis for the design of strip footings on expansive clays.

Also at this time Paul Walsh was working on a design procedure for stiffened raft footings. His early work which was available to us as associates in CSIRO, indicated that for a raft with longitudinal and cross beams at no more than about 4 metre centres, tables could be prepared for a given Δ/L and a soil heave or shrinkage of y_s. The information from both these researchers allowed us to produce a series of design charts for both raft and strip footings for all house types of different dimensions as seen in the example below.

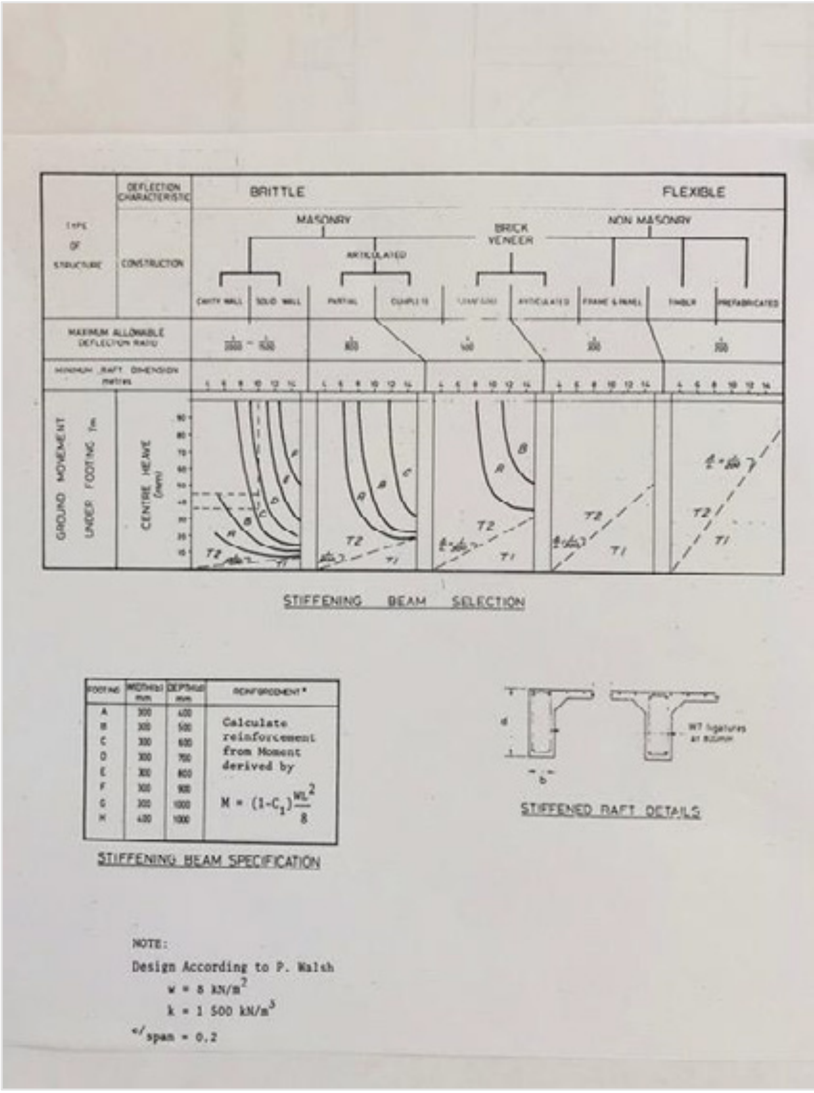

Figure 2: Design chart for the selection of raft stiffening beams according to Walsh 1974

As I left CSIRO in 1969 this final aspect of the work received very little exposure until it was recognized by the Institution of Engineers that more guidance for engineers was required. Consequently in 1979 a conference and publication ("the yellow book") on *Footings and Foundations for Small Buildings in Arid Climates* was held and the charts were published.

Also at this time, Peter Mitchell's procedure for the Structural Analysis of Footings was first published, and a developed form was published at the 5th International Conference on Expansive Soils in Adelaide in 1984. Both the Walsh and Mitchell methods became recommended design procedures and all that then remained to be sorted was the rest of the content for the Standard, AS2870 published in 1988.

POSTSCRIPT

Although I left CSIRO to join Coffey and Hollingsworth in Sydney after completing this work, I soon found myself back in their Adelaide laboratory using their equipment. As geotechnical consultants we had been appointed to design footings for a series of school buildings in Hay, NSW. Examination of a number of public buildings in that town showed that all were badly cracked due to the highly reactive clay foundation soils. For this reason a documented design procedure was required by the architects and the structural engineers. As Bob Lytton was still in Australia, we joined forces, with Coffeys conducting the site investigation and testing program and Bob cranking through the numbers for a design. The result was a series of stiffened rafts for the buildings which I believe have stood the test of time.

The approach was written up for the Third International Conference on Expansive Soils in Haifa in 1973.This paper was later included in the commemorative volume produced by the Australian Geomechanics Society for the Golden Jubilee of the International Society for Soil Mechanics and Foundation Engineering.

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From Australian Geomechanics Society News 1981 Mudline

Adelaide Soils Engineer:

"There is no gravity; the earth sucks"

DESIGN AND PERFORMANCE OF MAT FOUNDATIONS ON EXPANSIVE CLAY

R. L. Lytton, B.Sc., M.Sc., Ph.D., P.E., *Texas A & M University, College Station, Texas and*
J. A. Woodburn, B.Sc., M.Sc., M.I.E. (Aust.), *Consulting Engineer, Adelaide, South Australia*

SYNOPSIS A design procedure for stiffened mats on expansive clays has evolved over the past seven years and it has now been applied successfully on two continents in areas where expansive clay damage had previously been severe. The core of the design approach recognizes that soil support offered by differentially expanding and shrinking clay is influenced mainly by the changing moisture regime beneath a mat and the natural gilgai form expansive clay deposits. Empirical coefficients developed from a series of beam- and stiffened plate-on-mound computer analyses relate the predicted soil behavior to mat design quantities. The design procedure was applied to the design of school building foundations in Australia and field performance has been observed for over two years. The predicted soil movements were matched accurately by those observed and despite their magnitude, the mats have performed satisfactorily.

TASMANIA CHAPTER

On the 6th April 1970 the first meeting of the Tasmanian Group of the newly formed Australian Geomechanics Society was held in Hobart. The meeting featured a talk by Mr Lance Endersbee entitled "The Seismic Effects of Filling Large Reservoirs". Mr Endersbee at the time was a senior civil engineer with the Tasmanian Hydro-Electric Commission.

The Tasmanian Hydro-Electric Commission and its predecessor, the Government's Hydro-Electric Department, had necessarily become involved with what has become geotechnical engineering in the development of hydro-electric schemes in Tasmania. The original Hydro-Electric Department had been set up in 1914 when the state government took over the Waddamana power development. This development, by the Melbourne based Hydro-Electric Power and Metallurgical Company Ltd, had commenced in 1911 and aimed to use the waters of Tasmania's Great Lake and a steep 200m drop into the Ouse River gorge to provide electricity for the hydro-metallurgical processing of metal ores, particularly zinc ores mined in Tasmania. The processing works were initially located at Electrona south of Hobart but were subsequently moved to the Hobart suburb of Risdon. The Company had developed financial problems prior to the First World War and had negotiated with the state government for the purchase of the Waddamana development.

The state government appointed the engineer who had been in charge of the Waddamana works as engineer-in-chief and manager of the newly formed Hydro-Electric Department. This was John Butters who was then responsible for the expansion of the Waddamana power development and the extension of the electricity distribution system to the north as well as to the south of the state. John Butters resigned in 1924 to become chairman of the Federal Capital Commission, responsible for the establishment of Canberra as the national capital. He was knighted in 1927.

An indication of the Hydro-Electric Department's future involvement with geotechnical work was a comment in a 1915 construction review report that the head-works for the Waddamana development were still under construction with a note that "three small clay-core dams that would contain the waters of Penstock Lagoon (the pond for the penstock intakes) had yet to be completed". The works were completed by 1916 with the power station being officially opened in May of that year. Subsequent power developments would continue to involve geotechnical considerations in the construction of dams, canals, tunnels and other structures, with hydro-electric construction activities increasing after the Second World War.

It was thus that principally Hydro-Electric Commission civil engineers and geologists came together in June 1964 in Hobart for the inaugural meeting of the Tasmanian Group of the Australian National Society of Soil Mechanics and Foundation Engineering. The first technical meeting of the Group was held in Hobart in November of that year when Mr J M Maddox presented a talk entitled "Meadowbank Dam Foundation Investigations". Mr Maddox at the time was the engineer in charge of the Hydro Electric Commission's civil engineering laboratories in Hobart.

One of the prime movers in the establishment of the Tasmanian Group of the Australian National Society was Mr Lance Endersbee who, as noted above, was a senior civil engineer with the Tasmanian Hydro-Electric Commission. He had been the lead designer in the late 1950s and early 1960s for the Poatina underground power station that had involved innovative investigation methods and designs in rock mechanics to accommodate large natural rock stresses in the horizontally bedded sedimentary rocks in which the power station chamber was excavated. Mr Endersbee was Vice President of the International Society for Rock Mechanics between 1966 and 1970 and President of the Institution of Engineers, Australia, in 1980. He left the Tasmanian Hydro-Electric Commission in 1976 to become Dean of Engineering at Monash University in Melbourne and was Pro Vice Chancellor of that university at the time of his retirement in 1989.

Lance Endersbee, former professor of engineering at Monash University

Meetings of the Tasmanian Group of the Australian National Society continued during the sixties with four to five meetings each year. The venue for these meeting was the ground floor theatrette that the Hydro-Electric Commission had in its old Davey Street building and attendance at each meeting was about fifteen to twenty engineers and geologists.

The meetings of the Tasmanian Group of the Australian Geomechanics Society, which became a Chapter of the Society in the nineties, continued with about five meetings each year and with a greater proportion of technical presentations from other Tasmanian organizations such as the Mines Department and the Department of Main Roads, and from national and international speakers.

TASMANIA CHAPTER

Prominent speakers from the world of geomechanics have included Professor S Warren Carey from the University of Tasmania, the proponent of the expanding earth theory to explain plate tectonics; Professor Harry Poulos, an international expert on the design of pile foundations who presented the 2004 Terzaghi Lecture "Pile Behaviour, Consequences of Geological and Construction Imperfections"; and Tim Sullivan, who described the investigations associated with the 1997 Thredbo Landslide disaster.

Professor S Warren Carey from the University of Tasmania

While many of the Chapter meetings described geotechnical aspects of the design and construction of local Tasmanian works there have been a number of descriptions of overseas projects. Dr Glen Truscott described the construction of the Tarbella Dam in Pakistan and the foundation problems encountered in the construction of this dam. Professor Hamza from the Suez Canal University in Egypt described the construction of the Suez Canal. Dr Fred Baynes described slope stability problems associated with the construction of a railway in Tanzania. The Tasmanian Chapter has also hosted the presenters of annual lectures such as the Rankine Lecture (The Rankine Downunder) and the E H Davis Lecture.

In 1999 the Tasmanian Chapter successfully hosted in Hobart the eighth Australia-New Zealand Conference on Geomechanics. These conferences, and the former Soil Mechanics and Foundation Engineering conferences, have been held every four years since 1952 at venues around Australia and New Zealand. This 1999 conference was the first to be held in Tasmania and attracted 188 delegates with 32 of these coming from overseas.

A popular recent addition to the Tasmanian Chapter's programme of meetings has been one day bus tours to areas in Tasmania having various geotechnical and geological features of interest. About 20 to 25 local engineers and geologists have taken part in these tours with descriptions of features and potential problems at various stopping points by local specialist geologists and geotechnical engineers. In 2018 the bus tour visited the upper Derwent Valley and included an inspection of the Tarraleah penstock hillside which has been subject to a number of minor landslides since the construction of the penstocks eighty years ago. Other hydro-electric dam sites were visited together with a site at Macquarie Plains where there is evidence of ancient forests being inundated by volcanic basalt flows 5 to 10 million years ago.

In 2019 the tour visited the Tasmanian Midlands and included stops at two sites where incipient landslides had affected local highways. At one of these sites the State Roads Unit (Department of State Growth) had commissioned a geotechnical investigation to assess the safety of the road prior to a planned shipment of heavy wind turbine components to the Central Highlands. The road was assessed to be safe for the shipment and a long alternative route to the wind farm was avoided. A stop was also made at a large, though currently dry, shallow lake, Lake Tiberias, which occupies the largest deflation basin in Tasmania and has a 4km long lunette, now grass covered, along its eastern shore. This lake, and other similar features in Tasmania, are considered to be relict features that formed under colder, drier and windier conditions during the Late Pleistocene.

The Tasmanian Chapter of the Australian Geomechanics Society looks forward to many years of informative, stimulating and entertaining meetings dealing with things geotechnical.

2019 geological tour to the Tasmanian Midlands

This article was prepared by Tom Bowling

Vignette from *Australian Geomechanics News* July 1981

TASMANIA

Chairman: Tom Bowling, Civil Engineering Laboratories, Hydro-Electric Commission, G.P.O. Box 355D, Hobart, Tasmania 7001. (002) 72 6761.

Hon. Secretary: Bruce Cole, Civil Design Division, Hydro-Electric Commission, G.P.O. Box 355D, Hobart, Tasmania 7001. (002) 30 4628

Committee: Dick Barnett, Brian Cousins, Frank Kinstler, Bram Knoop, Ralph Rallings, Peter Stevenson, Ray Tarvydas, Alan Moon.

The Tasmanian Group has about 25 members, most of whom are resident in Hobart where all the meetings are held. Attendance at meetings varies from 20 to 35, depending on the topic. The audiences comprise a healthy mix of civil engineers and engineering geologists but regretably there is little participation by the Australian Institute of Mining and Metallurgy whose main strength lies in the mining towns on Tasmania's West Coast.

This imbalance was to some extent redressed in March 1980 when Jim Torlach, Chief Mining Enginer, E.Z. West Coast Mines, gave an excellent talk on Mine Design and Mining Practices at Rosebery where luckily the parent rock is very strong.

In May 1980, Brian Cousins from the University of Tasmania demonstrated the usefulness of Stability Charts for Earth Slopes. Brian has extended the range of previous charts and improved their presentation.

The Core Logging Symposium was held in July 1980. In the first session, three engineering geologists displayed and discussed drill core, core logs and geological maps. After a meal break, three engineers talked about the use of core logs at various stages of investigation and design.

In August 1980, when Professor Peter Lumb was fortuitously visiting his daughter in Hobart, our request for a talk was rewarded with a fascinating account of Geotechnical Problems in Hong Kong and, on another occasion, a lecture on Probabilistic Methods.

Our annual interstate guest speaker was Chris Jenkins, N.S.W. Maritime Services Board. He spoke in September 1980 on Newcastle Harbour Development for which enormous quantities of rock are being excavated by drilling and blasting underwater so that deeper draft carriers can use the harbour.

A feature of the year was a weekend technical visit to Launceston and the Tamar Valley in November. On Saturday the Hobart members and wives combined with a party from the Northern Group of the Institution of Engineers Australia to inspect the recently completed Curries River Dam, about 15km east of Georgetown. At Bell Bay Power Station, which is to be converted from oil burning to coal burning, the contingent inspected the boiler house and sites for the new boilers and ash dam. The party then proceeded to the plant of Northern Woodchips Ltd., where, following a generous tour of the works escorted by the Technical Manager, the members pondered on various stability problems connected with a railway embankment on dubious foundations. The return trip to Launceston included a pleasant stroll across the green pastures of an extensive landslip and mudflow area and a brief stop at a landslip stabilized with piling.

Vignette from *Australian Geomechanics News* June 1984

TASMANIA

At the Group's 1983 Annual General Meeting in October Alan Moon was installed as the Group's Chairman for 1984. Alan is an Engineering Geologist with the Mines Department and his interests range from the geological aspects of landslips to ground water investigations.

During November 1983 the Group organised an extra meeting in conjunction with the Tasmanian Branch of the Geological Society. This meeting was addressed by Professor Ding Yuanzhang from Canton, China. Professor Ding's field of expertise is Reservoir Induced Seismicity. In his talk he presented details of the increase in seismicity asso-

Vignette from *Australian Geomechanics* January 1990

GUEST EDITORIAL

CO-OPERATION - THE ENGINEERING ETHOS

Emeritus Professor

Lance Endersbee A.o., Hon. F.IE Aust.*

The idea underlying the formation of the Australian Geomechanics Society was the advancement of learning and practice in all aspects of geomechanics through the co-operation of all interested parties.

The society is jointly sponsored by the Institution of Engineers, Australia and the Australasian Institute of Mining and Metallurgy.

At the time, in the late sixties, when some of us were making moves to establish the Australian Geomechanics Society as a further development of learned activities in this field, I was a Vice-President of the newly formed International Society for Rock Mechanics, and a member of Council of the Institution of Engineers. I can recall discussions with members of the Councils of both IE Aust and Aus IMM concerning the prospect of joint learned activities in geomechanics. Co-operation was readily forthcoming, and the AGS came into being. Both Councils have been strongly supportive ever since, consistent of course with their many other responsibilities.

The nature of Geomechanics in professional practice is also based on co-operation. The geomechanics expert is often a member of a project team which may include structural and civil design engineers, mining engineers, civil construction engineers, geologists and geophysicists, and other personnel with office, field or laboratory responsibilities.

The creation and management of co-operative endeavour for a common purpose of practical achievement is one of the distinctive features of the engineering and mining community. We can call it the engineering ethos.

Texts on management rarely discuss the ethos for achievement, yet co-operation and teamwork are absolutely vital to the success of any joint endeavour such as an engineering or mining project.

Many of us can recall practical experiences where we shared with colleagues the satisfaction of a notable engineering or mining achievement - intellectual challenges of analysing problems and devising solutions, the happiness and friendship of working together in a supportive and co-operative way, and the pleasures of seeing ideas become reality as a successful project. It is difficult for those who have never worked this way to appreciate the nature of these challenges and the pride of achievement of the team.

It has also been my experience that the friendships formed among teams of engineers and scientists working together on challenging projects become firm and lasting. Because we are so dependent on personal co-operation with one another, we all must act with consideration and courtesy. Firm friendships arise in such mutual respect and understanding, and add a further dimension to the fascination of engineering and mining.

Our engineering ethos of co-operative endeavour is now steadily being weakened. Others are setting the agenda, and we are tending to follow their ways of confrontation rather than co-operation.

We have all been influenced by the excessive legalism now encroaching on much engineering and mining practice. The fear of possible litigation affects attitudes in all of us and leads us into much unnecessary work.

For example, there is a strong tendency to conduct site investigations from the point of view of providing an insurance against the later litigation rather than obtaining a reasonable and sufficient level of information on site conditions for the proper execution of the works.

Thus site and geomechanics investigations, and similarly, environmental impact studies, may be extended quite extravagantly beyond the real needs of the project and those of the community.

In construction, an increasing part of our (construction) management time is now directed to the acquisition of information for possible use in any subsequent litigation, rather than the proper technical management of the project.

Also, our consulting engineers and geomechanics firms are increasingly concerned about professional liability and possible litigation. This tends to compromise their advice and they feel compelled to take out more insurance.

There is the danger that the members of our project teams are losing sight of their true objectives and are anticipating conflict rather than co-operation. They thereby impose an unnecessary burden of costs on the community, which in turn lessens the international competitiveness of our industries.

It is understandably difficult to return to the simple ideals of practical achievement through co-operation and teamwork when the fashionable trend in our community favours increasingly complex legal and financial interactions. But it is a fashion, and the cold wind of market forces will inevitably have an impact.

In the meantime we should hold fast to the engineering ethos of co-operative endeavour.

Lance Endersbee

Lance Endersbee has worked for the Commonwealth Department of Works, the Snowy Mountains Authority, the Hydro-Electric Commission and Monash University. In his work he has aimed at being at the forefront of engineering development and innovation.

He has played a leading role in the profession's learned societies such as the I.E. Aust. of which he was President in 1980, the A.G.S. and the I.S.R.M. of which he was Vice President 1966-70.

Over the years he has, contributed to a wide range of technical publications, and to engineering education, and has been involved in specialist consulting and in legal matters as an expert witness.

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TASMANIA CHAPTER

TASMANIA CHAPTER COMMITTEES

Year	Chair	National Representative
1970		Mr Mike Fitzpatrick
1971		Mr Lance Endersbee
1972		Mr Owen Wilson
1973-76		Mr Dick Barnett
1977-79		Mr Ray Tarvydas
1980	Mr Glyn Roberts	Mr Glyn Roberts
1981-82	Mr Tom Bowling	Mr Bruce Cole
1983	Mr Tom Bowling	Mr Bram Knoop
1984	Mr Alan Moon	Mr Bram Knoop
1985	Mr R Barnett	Mr Bram Knoop
1986-87	Mr R Barnett	Mr Larry Polglase
1988-90	Mr Bram Knoop	Mr Tom Bowling
1991	Mr Brian Cousins	Mr Tom Bowling
1992	Mr Brian Cousins	Dr Fred Baynes
1993	Mr Brian Cousins	Dr Fred Baynes
1994-95	Mr David Brett	Mr Randal Colman
1996	Mr David Brett	Mr John Davies
1997	Mr Rick Donaldson	Mr John Davies
1998	Mr Rick Donaldson	Mr John Davies
1999	Mr Barry Weldon	Mr John Davies
2000	Mr Barry Weldon	Ms Kirsten Kuns
2001	Mr John Davies	Mr Paul Southcott
2002	Mr John Davies	Ms Rowenna Gilbertson
2003-04	Mr Paul Southcott	Dr Wayne Griffioen
2005-06	Mr Paul Southcott	Mr Fraser White
2007-08	Mr Andrew Ezzy	Mr Fraser White
2009	Mr Paul Southcott	Mr Fraser White
2010-11	Mr Peter Larratt	Mr Colin Mazengarb
2012	Mr Colin Mazengarb	Mr Adam Hedge
2013	Colin Mazengarb	Mr Gregg Barker
2014	Ms Nadia Vellar	Mr Gregg Barker
2015	Ms Nadia Vellar	Mr Nick Glover
2016	Mr Nick Glover	Mr Bernard Williams
2017	Mr Nick Glover/ Mr Colin Mazengarb	Dr Hongyuan Liu
2018	Dr Derek Pennington	Dr Hongyuan Liu
2019	Dr Derek Pennington/ Dr Ali Tolooiyan	Dr Derek Pennington/ Dr Ali Tolooiyan

1970 TO 1979

GIVING A DAM

The 1970s to the early 1980s saw the last phase of post-war construction of major water storage dams around Australia. In Victoria these included Cardinia, Sugarloaf, Thomson and Dartmouth dams. The Shoalhaven scheme was the largest and most ambitious project in NSW at this time, and is described in this chapter. In the other states, were Wivenhoe (Qld), Kangaroo Creek (SA) and in WA, the massive Ord River dam.

In the power sector, the Snowy Mountains Hydro-Electric Scheme was completed in the 1970s. Meanwhile, in Tasmania dam construction for power generation saw the building of dams such as Cethana and the iconic Gordon. The Tasmanian integrated hydropower scheme harnesses hydro energy from six major water catchments and involves 50 major dams, numerous lakes and 29 power stations with a total capacity of over 2600MW (source: ga.gov.au).

The double curvature concrete arch Gordon River dam in Tasmania, completed in 1974.
Photograph courtesy Stephen Fityus

IN MEMORIAM

AUBREY HOSKING 1920 – 2005

CHAIR 1974 - 1975

"Aub" Hosking occupied a prominent place in the materials branch of the Snowy Mountains Hydro-Electric Authority (SMHEA). He was closely involved in site selection and design inputs into the dams and tunnels of the Snowy project. He was "first on and last off" in about 14 of the principal dam constructions and became widely known among contractors and consultants.

Aub Hosking grew up in Western Australia. After leaving school he worked as an articled clerk with a law firm. He joined the army in 1939 and was posted overseas as a member of the AIF 8th Division. He was captured by the Japanese army in Singapore in 1942 and spent the rest of the war in Changi prison camp. Some of the forced labour operations carried out by the Australian troops involved the construction of light gauge rail tracks used for earthmoving in construction of an airport runway. He said that in spite of the harsh experiences he decided that after the war he wanted to be a civil engineer rather than a lawyer.

He graduated from the University of Western Australia as BE (Civil) with first class honours. He joined the scientific services section of the SMHEA in 1951 and set up the soil testing laboratory as part of the materials branch. He was chosen to take part of the in service training scheme run by the Snowy in coordination with the US Bureau of Reclamation.

In 1953-54 he spent a year at Imperial College, London University, where he received the award of Diploma. He chose as his thesis topic "The design of filter systems for incorporation in zoned earth dams". He became an acknowledged expert in the choice and deployment of reliable pore pressure and settlement sensors.

He was Vice-President of the International Society for Soil Mechanics and Foundation Engineering from 1977 – 1981.

HUGH TROLLOPE AO 1925 – 2011

CHAIR 1970 - 1971

Essential details of Professor Trollope's career achievement have been presented in the paper *The Early Days* in the previous chapter of this book.

The following paragraph is an extract from *The Birth of the Cyclone Testing Station - Personal Recollections* (2007) by George Walker (from the 30th Anniversary Celebrations of the Founding of the Station in November 1977).

*In 1964 a relatively young civil engineering academic from the University of Melbourne, Hugh Trollope, a Welshman by birth and still in his 30's who had established the science of geomechanics in Australia, became the first Professor at the *University College of Townsville with his appointment as the foundation Professor of Civil Engineering. He was a visionary who believed that the fledgling engineering department could become a major centre of civil engineering research in Australia, with a particular focus on issues relevant to North Queensland, and was determined to see his vision become a reality. It was this somewhat random combination of events that laid the foundation for the establishment of the James Cook Cyclone Structural Testing Station more than a decade later.*

**later James Cook University*

D H Trollope Medal

The medal recognises the contribution of David Hugh Trollope as one of the pioneers and leaders of Australian geomechanics research and teaching. This was initially at the University of Melbourne in the 1950s and early 1960s, then at James Cook University of North Queensland. Hugh Trollope was renowned as an eloquent, inspired and indefatigable leader of fundamental research, especially in the application of discrete particle mechanics in geotechnical engineering. Prof Trollope was one of the original pioneers of Australian Geomechanics teaching and research. The award may be made every two years, provided a suitable nomination is received.

SANDY LONGWORTH AM CHAIR 1972–73

Having spent one part of my professional life establishing and running engineering services and another part building and managing major resource facilities, I believe emerging engineers should include in their training, the study of one or more royal commissions or enquiries into major engineering failures. Studies should not be restricted to technical aspects but project decision making and management responsibilities. The Aberfan Wales and King Street Bridge Melbourne Royal Commissions and numerous expert reports furnished to underwriters of engineering failures prompts my twilight conclusions.

My team's contribution to Australian Geomechanics is recorded as a mere scratch on the surface of the big ball. Sixes escaped us, with plenty of middle order scores but no ducks. Notwithstanding, our game improved and we maintained our average, leaving our mark and training numerous new players along the way, before we lost the toss and our identity was sold.

It is with a cautious hand that I pick up my pen as the only surviving ex-chairman from the first three years of the now 50 years of age Australian Geomechanics Society (AGS). I will endeavour to recall what I can of my early years encompassing the formation of the AGS, the development of commercial Australian geotechnical services, projects and technology that influenced my work and a few of the people and organisations involved during this period. I have concluded at my age that memory and the retrieval therefrom are inversely related.

The Founding Fathers of Geomechanics in Australia were Dr Gordon Aitchison Head of Soils Division CSIRO which was initially located in SA but subsequently moved to Syndal Victoria, Dr Hugh Trollope who arrived at Melbourne University in 1950 and Mr E H (Ted) Davis who joined the Department of Civil Engineering at Sydney University in 1952 and was subsequently awarded a professorship. I was one of Ted Davis' early pupils.

While soil mechanics was taught at Sydney University pre-WWII, by Mr T D J Leech (Tommy), it was not until Ted Davis's appointment, influenced very much by Prof Jack Roderick, newly appointed head of the Department of Civil Engineering, that it was recognised as being of importance, in the teaching of the next generation of civil engineers. I think Jack Roderick would be very gratified to look back at the contribution to teaching and research that the staff members of the geotechnical section of the department have made to the engineering profession in general and to geomechanics in particular.

While relatively new, the soil mechanics discipline was progressing in the early 1950s. I worked during my student vacation in 1952, on the Rocky Creek earth embankment dam. A quite sizeable compacted earth core dam, engineered by GHD, to provide water supply for Lismore City. I spent time in the small, but well set up quality control laboratory facilities on site, undertaking index and compaction testing.

I was still an undergraduate when the first Australian New Zealand Soil Mechanics and Foundation Engineering conference was held in Melbourne in 1952, organised by Dr Hugh Trollope. Subsequently the Institution of Engineers Australia (IEAust) assumed responsibility for representing the growing number of geotechnical engineers and providing liaison with the International Society of Soil Mechanics and Foundation Engineers through an IEAust National Committee. Programs of regular technical meetings in the Divisions were still to emerge.

Growing professional interest, stimulated very much by academe, resulted in isolated groups of engineers coming together in a number of capital cities, enabling academic and practitioner groups to further their knowledge and share practical experiences. Ted Davis was the catalyst in Sydney, inaugurating a group of interested engineers that met regularly at Sydney University, initially calling themselves 'The Sydney Soil Mechanics Group'. This was in the early 1960s when Ted Davis ran what was possibly the first post graduate geotechnical course, at Sydney University, in Foundation Engineering in 1961.

In 1970 the AGS was formed, sponsored by IEAust and the Australasian Institute of Mining and Metallurgy (AusIMM). Ms Beryl Jacka, the very capable long time secretary of the AusIMM, of which I was a member, played a very vital role in setting up the joint IEAust and AusIMM meeting in Melbourne, which secured the combined members assent to the formation of the learned society.

This was done following a Melbourne geotechnical conference. The inaugural members were predominantly geotechnical engineers, with a few mining and engineering geologists from Mount Isa Mines Limited and the Snowy Mountains Hydro-Electric Authority SMHEA. .

The conference organisation and attendance was very much due to the efforts of Gordon Aitchison, Hugh Trollope and Ted Davis.

Ken Mosher, a very active AusIMM committee member, worked from the Sydney end with the IEAust to bring the project to fruition. Dr Gordon Aitchison was the 1971 inaugural chairman of the AGS and I followed him in 1972.

In 1973 the Australian Tunnelling Association was spun off as a specialist group from AGS and I was the inaugural chairman. Active interest in tunnelling was emerging in Melbourne at this time with the extension of the metropolitan rail transport network.

It was around this time that I was on a committee with Dr Alan Hargreaves, department head of Sydney University mining engineering, which organised a Rock Mechanics symposium at Sydney University, possibly the first professional gathering of its kind, addressing this emerging art. I remember the symposium well, as Hugh Trollope complained about the size of print in the papers presented; he was short sighted. I apologised on behalf of the committee, saying we had made this choice to meet the symposium budget.

In the 1950s subsurface investigation for major works was usually carried out using test holes and pits, water bore percussion drills, auger earth drills and diamond drills. Engineering geologists were almost exclusively to be found in major government entities. Noel Grey was the Metropolitan Water Sewerage and Drainage Board engineering geologist responsible for the engineering geological investigation for the Warragamba Dam, which was in the early stages of construction at the time. The site investigation was still in progress, verifying the sedimentology, and employed large diameter calyx drills enabling the geologists to descend for logging purposes. I visited the site with a university engineering geology group field excursion in 1952. At the time there was co-operation between Universities and Government Departments in providing limited professional and testing services to consultants and industry. Colin Adamson, geologist with NSW Department of Mines, by arrangement with the then Director Toby Rose, provided ad hoc geological advice for engineering projects to consultants and industry. Toby Rose was for some years chairman of the advisory committee to the School of Geology at NSW University of which I was a member.

In 1955 as a young engineer I was entrusted with the engineering for the footings for what was to be the Bank of NSW, a new substantial masonry clad bank, as banks were in those days, to be built in Murwillumbah NSW. The site was not far from the Tweed River, on an estuarine clay flood plain. Site investigation consisted of 2 holes drilled to about 12m depth by the local water boring contractor. This satisfied me, as inexperienced as I was, that a pile foundation should be adopted. A few other substantial buildings in the area had been founded on local turpentine timber piles.

In 1959 David Coffey established his geotechnical engineering firm in Sydney. I had not long set up in engineering practice with Alan McKenzie in Crows Nest Sydney and David introduced his consulting site investigation services to me. David's firm grew progressively and Coffey International Ltd became an ASX listed company in the late 1980s. This was a significant achievement for an Australian engineering service company, possibly the ASX's first listed professional engineering services company.

It was also in 1959 that George Wimpy from UK established an office in Sydney and Foundation Engineering, a subsidiary of John Mowlem a British construction company, set up operations in Melbourne. George Wimpy's site investigation services were managed by Malcolm Wood. Wimpy had moved to Australia to undertake engineering and investigation work at Rum Jungle NT and Mary Kathleen in Qld, for uranium mines being developed by the Zinc Corporation, for the British Government's nuclear program. Dr R H G Parry was the manager of Foundation Engineering and both organisations were possibly the first commercial entities to establish laboratories with triaxial soil strength testing facilities. This was no doubt stimulated by the work of Bishop & Henkel at Imperial College London. At the time, there was a very strong leaning towards British technology and practice in Australian geomechanics. The SMHEA was an exception, entering into a Technical Service Agreement with the US Bureau of Reclamation in the early 1950's and establishing modern well equipped laboratory facilities in Cooma NSW. These facilities, initially focused on rock mechanics and concrete technology, there being a large content of tunnelling and concrete dam construction in the initial stages of the project. This became more soil mechanics orientated with the construction of the Eucumbene and Blowering dams towards the end of the project.

Frankipile, a Belgian based piling company, established in Australia in the 1950s and subsequently set up an investigation subsidiary, Ground Test, in Sydney. Don Douglas managed this company and with participating partners, acquired it from the parent in the 1970s, when the name was changed to Douglas & Partners. In 1963 I started a geotechnical division within Longworth & McKenzie (LM), by then an established, Sydney based engineering firm. The firm expanded over the years, with ownership changing after my retirement. The geotechnical division broke away from the parent, with a name change to Longmac Associates, following the sale of LM to Pak Poy Consultants. Longmac Associates principal was Dr Laurie de Ambrosis.

The company was subsequently purchased by GHD with a change of name to GHD Geotechnics, with Laurie de Ambrosis continuing as principal.

The geotechnical division of LM also had a very well equipped soil testing, and to a limited extent, rock testing, laboratory. In those early years it was one of only 2 or 3 commercial soils laboratories able to carry out triaxial and oedometer testing. In the early 1970s demand for this line of more sophisticated soil testing grew. Previously universities had hired out their testing facilities for commercial purposes. Geotechnical firms also sought to increase the quality of their testing facilities and become NATA registered.

Of particular relevance were the cells used for triaxial testing. At the time these cells were of British design, incorporating a precision lapped sleeve for the load plunger, necessitating the use of castor oil for topping up the cell water to minimise cell leakage and maintenance of cell pressure. To eliminate the use of smelly castor oil in the laboratory and for improved reliability, an in-house design was produced and built by LM, incorporating recently developed linear ball bearings and a teflon seal to replace the lapped sleeve. Later, in the early 80s, LM's laboratory efficiency improved through the automation of strength testing, test programming and other procedures. Dr Tim Hull, from Sydney University, worked with the firm over a number of years bringing this work to fruition. Other geotechnical service companies in the 1960s and 1970s were Dames and Moore, managed by Dennis Hodgson and Brickhill Moss, being the forerunner in Australia of Golder Associates.

In 1966 the Aberfan disaster occurred, bordering this Welsh coalmining township. This started as a traditional slip failure near the top of a large coal reject dump, on the slopes of Merthyr Mountain and developed into an extensive mud run of liquefied coal reject, partly demolishing a school and killing 144 people, which included 116 children at the Pantglas School. The slip was augmented by the highly saturated downhill material, emplaced over an active spring, which emerged from the sedimentary stratigraphy, becoming more active following an extensive wet period.

Prior to the disaster, LM had commenced investigating the stability of a significant emplacement of coal waste within Stony Creek, adjoining Coalcliff Colliery in NSW, located uphill from the coastal Coalcliff village, in a not dissimilar environment to Aberfan. This disaster focussed my mind and prompted me to consult Ted Davis. Together we visited the site and Ted insisted on driving me to Coalcliff in his Riley sedan, recently overhauled, with the assistance of the faculty workshop mechanic, a colleague of Ted's. Ted was very fond of cars and driving and insisted on travelling via the longer coastal road, which was quite tortuous, necessitating plenty of gear changing, which made his day.

Ground water levels in the dump needed to be established and commercial piezometers were not readily available in those days. Some novel piezometers were created, with the ingenuity of one of our engineers, the late Jack Hodgson, who was an inaugural AGS member and one time AGS committee man. This disaster prompted a number of the collieries, operating along the escarpment within the Sydney Basin, to review their coal reject emplacement facilities and practices and was the start of significant geotechnical investigation and design work for LM. I studied the findings of the Royal Commission into the Aberfan disaster in detail and subsequently gave a talk to The Sydney Soil Mechanics Group on the incident. In retrospect I concluded that, it was very sobering, for aspiring geotechnical engineers to study in detail, early in their career, events such as Aberfan.

The weathered talus slopes of the Illawarra region have a long record of landslide instability, associated with a number of the sedimentary geological strata, particularly following long wet periods. This is due principally to the build up in artesian pressure, manifest along the underlying perimeter basin edges. This was the early start of formal geotechnical understanding of the terrain behaviour, particularly following prolonged wet periods. Prior to this, Harry Bowman a geologist with the NSW Department of Mines, produced a very useful map, identifying potentially unstable areas. This map was used by Wollongong Council for many years, as a reference in approving building applications and land subdivision developments in the slip prone region.

Continuing work in the Illawarra, associated with landslip prone terrain, led in 1970, to the development of slotted pvc drains, inserted in inclined drill holes within the unstable areas, which proved effective in reducing the groundwater pressure and arresting landslides. These drains were used very effectively on major surface works within the escarpment talus for the Coalcliff Colliery in the 1970s and are now extensively used for slope stabilisation.

Andrew Shirley was one of LM's engineers who pioneered our first use of these drains, which became widely used and were introduced to the then Department of Main Roads in NSW, to stabilise a slip which developed in a section of the Barrenjoey Road at Newport. Other engineers who became experienced in the geotechnical behaviour of this coastal region from the Illawarra, Northern Beaches and Central Coast areas and with whom I worked were Andrew Leventhal, Keith Seddon and Garry Mostyn. Greg Kotze, an engineering geologist, became actively involved in land stability, as did Laurie de Ambrosis. Their work covered large subdivisions in the Gosford, Wyong and Castle Hill areas.

Another of LM's engineers, of relevance to this reminiscence, was Tanya Kouzmin, who was Australia's first female geotechnical engineer and the first LM female engineer to join the team in 1973. Tanya was a good proof-reader of reports and is currently the editor of *Australian Geomechanics*. It was around this time that Andrew Leventhal's skills were attracted to the understanding and management of landslip terrain in the region. Andrew has subsequently made a very substantial contribution to analysing and controlling this phenomenon.

Development on the Gold Coast was becoming very active at this time which involved LM in numerous pile designs for high rise projects working with Lyall Dickenson of Edwards Building Services, a Sydney based earth boring and piling contractor.

There was also quite a breakthrough in the late 70s, with NSW Public Works making greater use of geotechnical consultants and awarding LM an extensive investigation for the Gosford Wyong Sewerage extension covering the water crossing of Tuggerah Lake, overland trenching, tunnels and the ocean outfall at Norah Head. Peter Stone was active in the execution of this project.

Open pit surface mining had developed into a major industry in Australia in the 1970s. Iron ore and coal production dominated this form of mining but due to the tabular nature of these minerals, producers saw no real cost benefits from the application of rock mechanics to mine planning. A wild card in this sector was the Marulan NSW open pit limestone quarry operated by Blue Circle Southern Cement and now Boral. This pit supplied both the steel and cement industry with high quality limestone. I had a good understanding of the Marulan pit operation, having been involved in waste disposal planning and expert witness appearance in the Mining Wardens Court, for Southern Portland Cement and the Blue Circle Cement companies. LM were consulted regarding development of a long term plan for the limestone pit, which was scheduled to deepen significantly. A decision was made to involve Dr Barry McMahon in this project, which led to a very amicable working relationship between the parties. Laurie de Ambrosis worked with Barry on this project, which adopted very advanced analytical methods at the time. LM and in particular Laurie de Ambrosis and Barry McMahon subsequently undertook quite a lot of unique stability work, involving iron ore mines on Cockatoo and Koolan Islands WA. Feasibility studies were carried out for deepening the Cockatoo Island mine to below sea level by building a coffer dam around the ore body. At Koolan Island, working with Barry McMahon, investigations were undertaken into the construction of large mullock dumps over mangrove mud swamps, all very novel at the time.

The firms involvement in underground coal mine planning, prompted me to approach my first employer, CMPS, to compete in a joint venture with LM, for the exploration and long term mine plan for the Mae Moh lignite mine in Northern Thailand, a project for the Electricity Generating Authority of Thailand (EGAT). The project involved extensive open hole resource drilling and downhole geophysical logging for coal quality assessment, geotechnical core drilling and seismic traversing, for resource measurement and collection of geotechnical data for mine design. Slope design and detailed mine planning were also undertaken, to establish the viability of the mine as a source of lignite for power generation and to support the subsequent application by EGAT, for a loan from the Asian Development Bank. The lignite was multi seam and extensively faulted, in a tropical high rainfall area.

Ron Hansen and Sandy Longworth
Chiang Mai Thailand 1979

LM managed the site operations which involved mobilising a sizeable site team some of whom involved Andrew Leventhal, the late Ron Hansen with Laurie de Ambrosis working in the Sydney office. Ron Hansen's wife Ilsa managed the site office. The team lived and had catering arrangements on site. The project payment terms were an irrevocable letter of credit, not a normal payment instrument in the geotechnical business at the time and EFIC underwrote the join venturer's performance bond which was beyond the venturer's financial means at the time. An export award was received for the project. Geotechnical engineering has its challenges and this project presented many of these leaving us with many interesting memories, not all geotechnical.

Drilling- open hole - mud stabilisation- downhole logging, Mae Moh, Thailand 1979

The late 70s and early 80s were active years in the Australian coal industry particularly in the Hunter Valley, where LM set up a permanent office servicing a number of major mine developments. The Hunter Valley coal expansion activity prompted the development of stage 1 of the Kooragang Island coal terminal, now one of the world's largest export terminals, a project in which I was actively involved, managing our engineering skills. Peter Stone played a key role in the geotechnical investigation of this project, in particular the systematic preloading of the stacking and reclaiming machine tracks and materials handling facilities within the extensive stockyard, located on the soft estuarine site. The Stage 2 of this project has now been completed and I understand GHD's Geotechnical engineer, Peter Stone, contributed his skills to this work prior to his retirement.

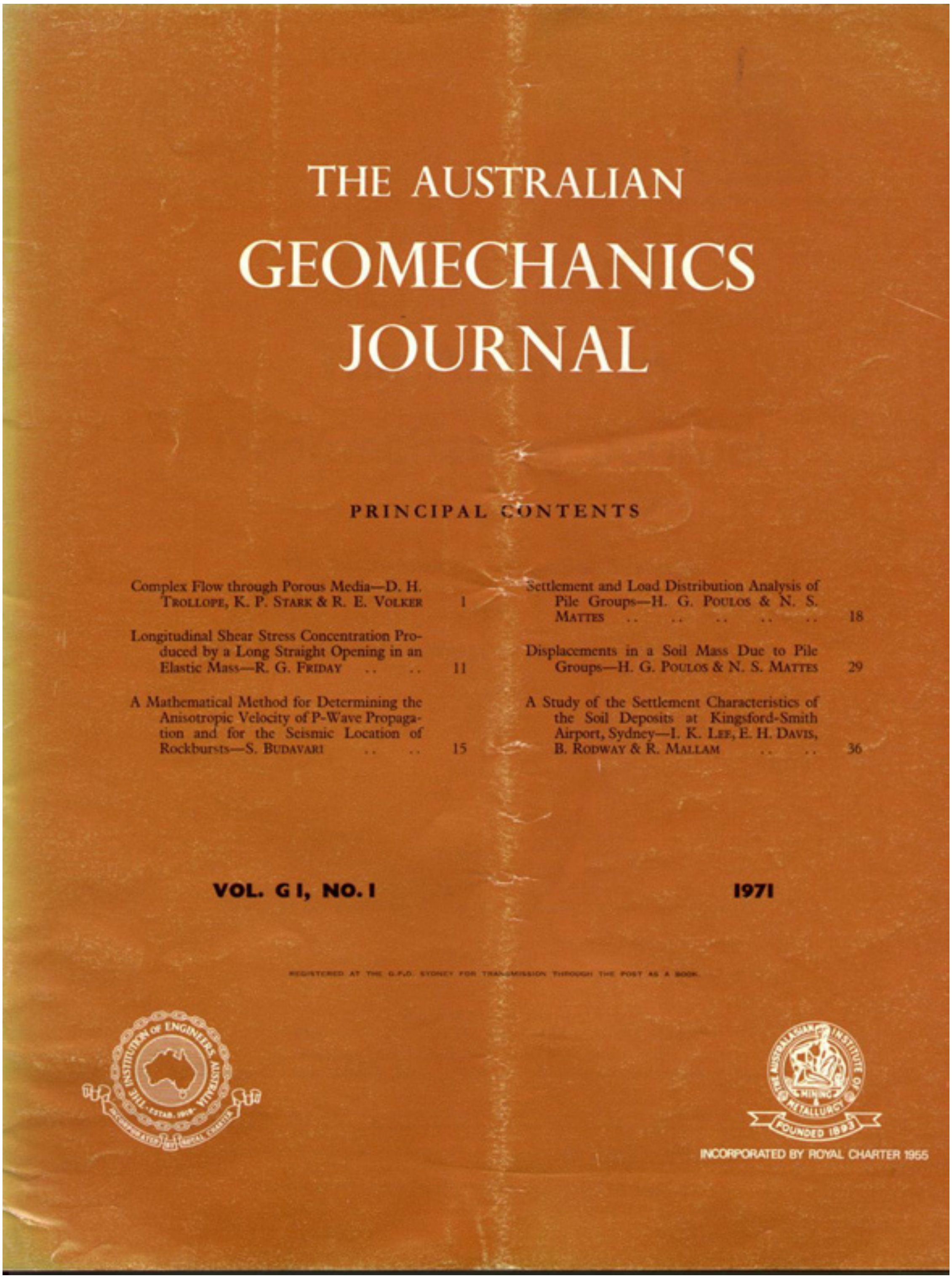
LM's initial Hunter Valley operations were managed by Paul Robinson and based in the Warkworth Primary School, a delightful old school building with provision for the pupils to tie up their ponies. The school became part of the Hunter Valley No. 1 mine site. Permanent operations subsequently moved to Singleton and were managed by Ross Killick, who joined the company as a technician and went on to qualify as a geotechnical engineer. Another LM geotechnical engineer who came up through the ranks from a technician was Ian Barnett. LM trained over 100 apprentices in engineering sub professional roles before the ownership of the company changed hands.

Two areas which were in a sense ground breaking for geotechnical engineering at the time, were the application of selected mine waste for water retaining structures and the prediction of mine subsidence settlements and associated foundation design, to accommodate subsurface movements generated from mining. Brennan's Creek Dam provides the water needs for Westcliff Colliery in the Illawarra Region of NSW. It is a novel embankment dam constructed from compacted selected coarse coal reject, which was abundantly available near the site, with an impervious asphaltic concrete upstream membrane. This was a project which Andrew Leventhal guided to fruition assisted by Keith Seddon and Robert L Smith. LM's introduction to subsidence predictions and associated foundation design was headed up by Laurie de Ambrosis and initially focussed on HV transmission line structures constructed above areas to be undermined by coal extraction in the Hunter region. Andrew Leventhal has carried on the work in this field which has become more sophisticated following the introduction of longwall mining methods.

I have been involved in a small part of the early life of the AGS, which if success can be measured by the level of penetration of geomechanics into the building of a nation, puts this learned society at the top of its class. When I look back to my humble beginnings, I see the AGS as a great achievement, not only due to the contribution made to the advancement of geotechnical knowledge by our expert professionals but by the enterprise and quality of Australian geotechnical engineering as an essential service industry, which has contributed to major engineering works both within Australia and abroad. The AGS, whose members are its strength, has played a key role in this achievement. They are to be congratulated on this half century of achievement.

Brennans Creek Dam, to this day, is the main water supply for the washery at West Cliff Colliery, near Appin, NSW. It has a 100mm thick upstream bituminous concrete membrane. The dam is on the World Register of Large Dams, and was designed to accommodate the impacts of mine subsidence. The embankment is 17+m high with batter slopes at an angle of 2:1 (H:V), and manages PMF flows by way of an uncontrolled side-channel spillway. The photo, from July 1976, shows the construction of the second 50mm thick layer, using a paver modified to operate on the embankment batter (one of the designers, Andrew Leventhal, for scale).

Cover of the very first *Australian Geomechanics* Journal, 1971



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PRINCIPAL CONTENTS

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LESSONS LEARNT DURING THE CONSTRUCTION OF THE SHOALHAVEN SCHEME, NSW

JOHN BRAYBROOKE

John Braybrooke is a Senior Consulting Engineering Geologist with over 50 years of post-graduate experience in all facets of engineering geology, ranging from house sites to large scale infrastructure projects. John has worked in all states of Australia as well as Papua New Guinea, New Zealand, Indonesia, Malaysia, Philippines and Western Samoa.

John's areas of expertise include civil and mining underground structures, particularly tunnels, declines, drifts and shafts, having been involved with over 250 underground projects. He also has extensive experience with dams, ranging from mine dams to a hydro-electric dam in Malaysia. He was the resident engineering geologist in the 1970's on the Shoalhaven water transfer and pump-storage scheme, a mini Snowy Hydro Scheme with 4 dams, 2 tunnels, 3 power/pump stations, canals and pipelines.

1 INTRODUCTION

As part of their future planning for Sydney's water supply, in 1960 Sydney Water developed the concept of transferring water from the Shoalhaven River to Warragamba Dam. They investigated the Welcome Reef dam site on the upper reaches of the Shoalhaven River together with a 40 mile long water transfer tunnel to the Wollondilly River and thence to flow into Warragamba Reservoir. Knowing that the government of the day would not accept such an expensive scheme without it being subject to an external review, they asked the Snowy Mountains Hydro-Electric Authority (SMHEA) to review their scheme, hoping for a sign-off in principle.

SMHEA looked at the scheme and developed several possible alternatives. Finally they came up with the concept of a relatively low weir on the lower Shoalhaven (Tallowa Dam), just below the confluence of Kangaroo and the Shoalhaven rivers, transferring water up to a holding dam on the Wingecarribee River in the Southern Tablelands of New South Wales. This water transfer scheme would not only provide additional water to Sydney but also to the South Coast as well as being a hydro-electric pump-storage scheme with the ability of being duplicated at some time in the future, doubling its power generation capacity; in fact this duplication is currently being investigated at a feasibility scheme level.

The transfer scheme required the weir, Tallowa Dam, to form Lake Yarrunga, backing water up the Kangaroo River to a pump-power station, Bendeela Power Station. From here the water was pumped up a pipeline to a small intermediate holding pond, Bendeela Pond, with Kangaroo Valley Power/Pump Station at the rear of the pond. Water was then to be pumped up Kangaroo Tunnel, Kangaroo inclined shaft and pipeline to Fitzroy Falls Canal. Water was to then flow along the gravity canal into Fitzroy Dam which was to have a controlled outflow to keep Fitzroy Falls, a tourist attraction, flowing.

From the back of Fitzroy Falls Reservoir water was to connect into Wildes Meadow Canal to Burrawang Pump Station. From here water was to be pumped through Burrawang tunnel into the Wingecarribee Reservoir. Finally, water could then be released down the Wingecarribee River to Warragamba Dam or through an open cut, Glenquarry Cut, to eventually flow into Nepean Dam and thence into Wollongong and associated areas.

The Scheme was investigated in the late 1960s to early 1970s with construction starting in 1971 and being completed in 1977. As the Resident Engineering Geologist for the scheme I learnt a number of lessons that have stayed with me.

2 REGIONAL GEOLOGY

The scheme lies near the southern margin of the Sydney Basin, an uplifted and gently deformed sequence of sedimentary rocks of Permian, Triassic and Tertiary age. In this area the Shoalhaven and Kangaroo rivers are deeply entrenched in a formerly extensive tableland, of which the main remnant in the project area is the Robertson Plateau. The valleys are mostly youthful and precipitous, with their profiles influenced by the resistance to weathering of the various rock types. The more readily weathered rocks, such as shale or siltstone, usually form moderately steep slopes, while the more resistant rocks such as sandstone, form terraces in the valley floor or pronounced steps and cliffs up to 150m high in the valley walls. Debris from ancient landslides and rock-falls mantles the lower valley slopes.

The full stratigraphic sequence of the Sydney Basin is present in the vicinity of the works (see Figure 1), ranging from Tertiary aged basalt, diatremes and sand deposits to the Conjola or Snapper Point Formation at the base of the basin overlying Ordovician aged low grade metamorphic basement rocks, present in the foundations of Tallowa Dam.

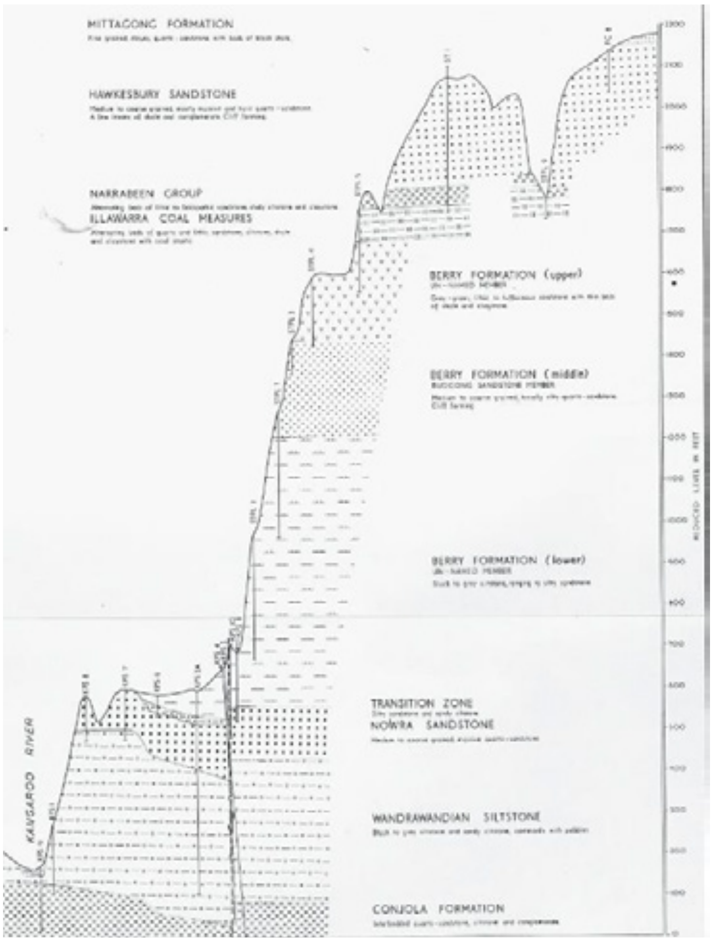

Figure 1: Sydney Basin stratigraphy

3 BENDEELA POWER STATION

The power station lies on the right bank of Lake Yarrunga, at the foot of a steep, under-cut slope within the Wandrawandian Siltstone. The station comprises two 41MW units located within a 30m deep by 27m diameter pear-shaped silo, with two intake/outlet structures separated by a spear-head shaped splitter wall. In an attempt to save on back-fill concrete the splitter wall was to be left as a rock pillar encased in concrete.

The siltstone comprised horizontally bedded siltstone and sandy siltstone with bedding planes generally spaced up to 0.6m apart with two main, near vertical joint sets striking NNE and ESE spaced at up to 5m.

Excavation of the station was by drill and blast methods with alternative blasts on each side of the intake/outlet works. As blasting progressed the joints in the pillar, nicknamed Cleopatra's Needle, were mapped and then drawn up on an isometric section. The projection of one joint day-lighted on the northwest face of the pillar. This joint block was removed. The projections of all the other joints fell within the base of the pillar.

It was decided to retain the pillar which was then tied together by rock bolts and bars threaded through the pillar and fixed to steel channels on either side of the pillar. The pillar was then covered by ARC mesh and shotcreted. Even though blasting continued to cause some movement of the pillar it remained intact. In hindsight, it would probably been far more cost effective if the intake/outlet structure had been bulk excavated and the splitter wall formed up in mass concrete.

Two months after the start of excavation a burden blast undercut a 270m^3 joint block which slid out (see Figure 2). Later on, another potentially unstable joint block was identified which was removed by light blasting. A third, potentially unstable, joint block of 3,700m^3 was identified. Structure contouring indicated that it was likely to sit on a base.

After reviewing all options it was decided to stitch up the sides of the wedge, to monitor it for movement by precise survey methods and to continue to geologically monitor the joint orientations as the excavation continued. The excavation was completed successfully without movement of this wedge.

Figure 2: Failed joint block, Bendeela Power Station

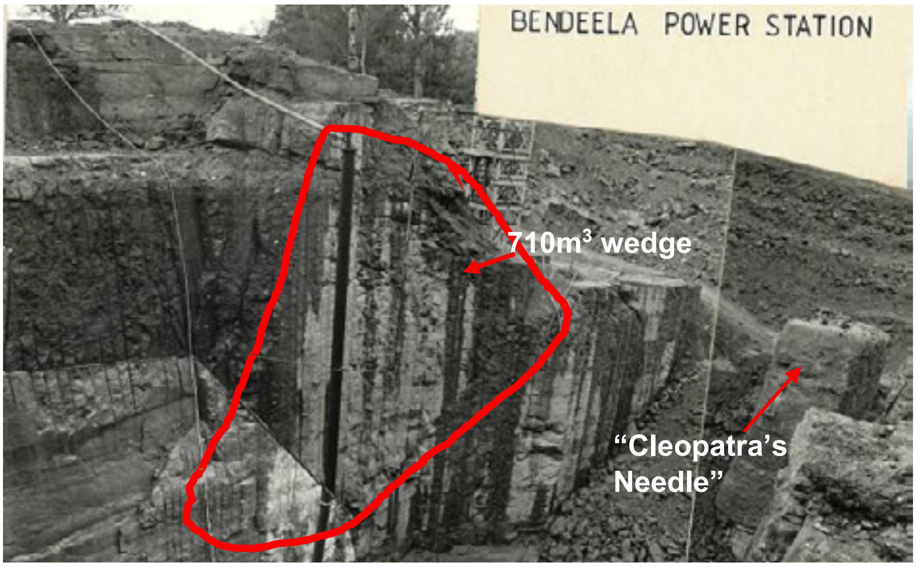

Figure 3: Bendeela Power Station shows Cleopatra's Needle and large wedge on southern side of silo (outlined in red)

Finally, yet a further 710m^3 wedge was identified on the southern side of the silo (see Figure 3). Structure contouring of the initial orientations of the joints indicated that the wedge would sit on a small base of approximately 1.2m^2 but, if the joint orientations became more adverse it was obvious that the wedge could not be economically retained.

The sides of the wedge were stitched and the wedge was geologically monitored as excavation continued. Finally, in early January 1974, the unthinkable happened; the wedge day-lighted but it stayed in place. From a wedge stability analysis, for the wedge to have a Factor of Safety of at least 1.0, it must have had an effective friction angle of 41^0 and zero cohesion or a friction angle of 39^0 and at least a cohesion of 3 kPa, neither of which were too far outside previously laboratory measured values, taking roughness into account.

Removal of the wedge at this stage would have significantly disrupted the construction program so it was decided to place tell-tales across the joint traces and to carry out precise levelling of points either side of joint traces following each blast.

Precise levels were read to 0.01mm with repeatability of each reading of 0.05 to 0.15mm ! (This is as good or better than what we are doing today with most "precise" levels today being +/- 1 to 2mm).

At the same time Ken Sharp, Head of the Geology Group, SMHEA, suggested that the wedge be monitored for sub audible rock noises (SARNS) using very sensitive geophones and manually counting the number of clicks per minute (using headphones) after each blast. The alert level was set at 100 clicks/minute while the alarm level was set at >500 clicks/minute (cf Goodman & Blake, 1965; 1966 and Wisecarver et al, 1969) who had reported noise rates of >300 up to 2500 clicks/hour in unstable slopes). Generally there was a low level of rock noise (<50 clicks/hour) though immediately after some blasts the noise rate exceded 1200 clicks/minute but settled back to <50 clicks/minute within 15 to 20 minutes. Two weeks after the start of monitoring there was a sudden increase in noise, peaking at 1140 clicks/minute over a 6-minute period; the wedge just as suddenly quietened again.

While this monitoring was occurring the river flooded, overtopping the coffer dam and filling the silo excavation. This caused a slight rise of the two wedges being monitored by 0.15 to 1.1mm. Overall though there was a slight settling of both wedges by 0.15 to 0.5mm, of the same order of magnitude that would be expected for deformation of massive rock under self-weight when lateral support is removed.

Although concern was expressed by some at the decision to retain both rock wedges, particularly by the contractor, fears were allayed by keeping everyone informed about the results of the stability analyses and of the monitoring. The successful completion of the pumping station with only minor rock movement, and the lack of post-construction problems, confirmed that retaining the rock wedges was the correct decision (Braybrooke, 1987).

Figure 4: Bendeela Power Station flooded

4 BENDEELA PONDAGE BLOCK GLIDING

The pondage is a regulating basin between Bendeela and Kangaroo Power Stations. It is located on a relatively flat-topped ridge that is bounded by a low line of cliffs comprising Nowra Sandstone overlying Wandrawandian Siltstone. What was intriguing was that within the cliff-line there were large open joints up to 3m wide and 10m deep while immediately below the cliff-line there were a series of large, up to 100m long by 30m wide, blocks of sandstone separated from the cliff-line. Further downslope there were smaller detached blocks

Similar detached blocks of Nowra Sandstone, up to 30m high and separated from the adjacent cliffs by 100m, have been described by Young & Young (1992) and ascribed to extremely slow creep giving rise to block gliding. As Young & Young note, explaining the gliding of these block is difficult as there are no highly plastic beds at the base of the Nowra Sandstone, only siltstone, and the sites are well drained. (Similar gliding blocks, but on a much smaller scale, can be seen below some cliff lines within Hawkesbury Sandstone, associated with thin shaly beds).

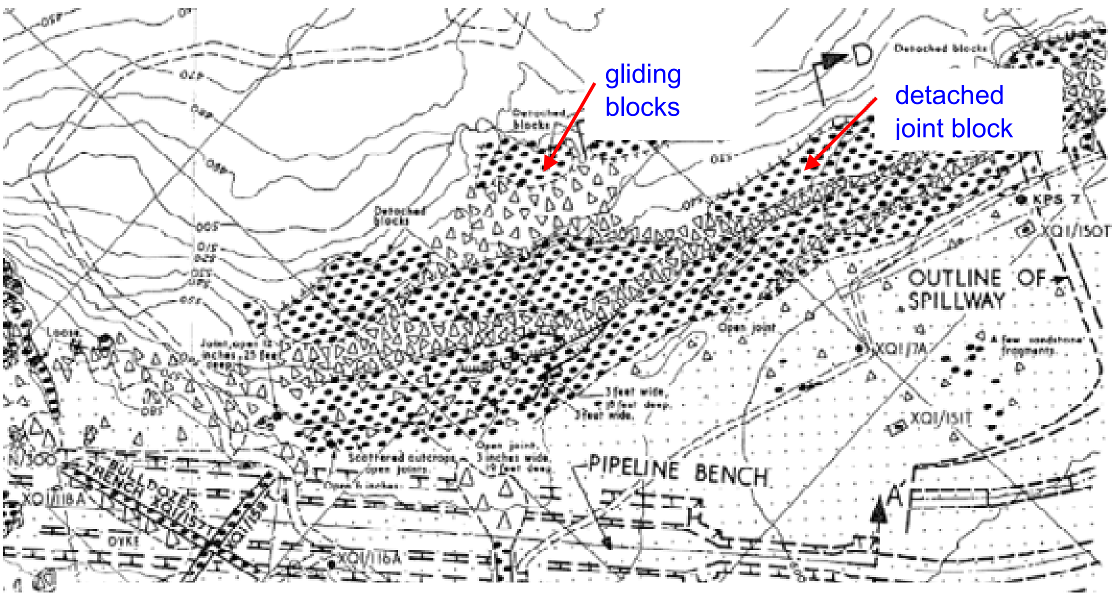

Figure 5: Bendeela Pondage, gliding blocks

5 KANGAROO VALLEY POWER STATION

5.1 Acid Sulphate Rock

The power/pumping station lies at the back of Bendeela Pondage within a 46m deep open cut, mainly excavated within medium to high strength (15 - 35 MPa) silty sandstone/sandy siltstone (quartz greywacke) of the Berry Formation. The rocks are composed predominantly of poorly sorted detrital quartz and lithic fragments, minor detrital mica and elongated shreds of carbonaceous material in a clay to silt sized argillaceous matrix comprising quartz, clay minerals and sericite. Microspherular pyrite is present in trace to minor amounts as single grains scattered through the interstitial clay and along grain boundaries, as small aggregates or associated with carbonaceous material see Figure 6). A carbonate cement occurs as fine-grained dolomite and siderite crystallised in many interstices or as irregular grains of calcite.

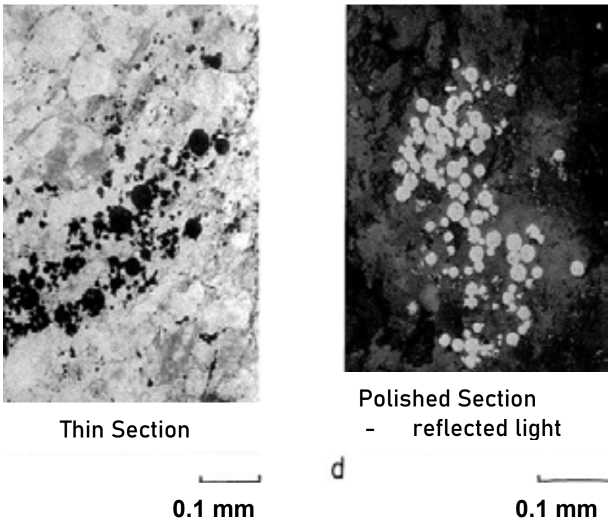

Figure 6: Berry Siltstone Photomicrograph showing micro-spherular pyrite

On exposure to wetting and drying the rock develops surface cracking which extends to depths of 50 to 150mm within a year in exposed situations. The cracks are often limonite stained with light dustings of white (gypsum) or yellow efflorescence, conditions similar to those seen in the Wianamatta Group of rocks (Ashfield and Bringelly Shales). This breakdown appears to be a combination of shrink-swell associated with wetting and drying and with oxidation of pyrite in association with organic matter producing sulphuric acid which attacks the carbonate cement (Swaine, 1971). (The most spectacular example of this break-down was during excavation of the Liddell Power Station intake - outlet canal in the Hunter Valley. The canal was excavated through siltstones of the Mulbring Siltstone formation, the stratigraphic equivalent of the Berry Siltstone. During excavation, rock in at least one section of the canal broke down overnight with steam being observed rising from the excavated area early the following morning, Swaine op cit).

5.2 Blast Cratering

The main excavation of the open cut, within fresh rock, was carried out by way of a mass burden blast between RLs 184 and 170m. Pre-split holes were drilled at 1.5m centres and fired using 0.15kg of explosive per square metre of face, followed up by a mass blast. The mass blast used blast holes on a 3m by 3m square pattern with the upper 3 metres stemmed and 12,750kg of explosive (AN60 plus ANFO) within a rock volume of 54,000m^3; a powder factor of 0.24kg of explosive per m^3. The blast did not effectively fragment the rock, leaving numerous blocks up to 7.6m^3 in volume, some of which had to be blister blasted, but, due to the poor fragmentation, below RL 178m the area was re-drilled in a chevron pattern and blasted in stages with powder factors of up to 0.8kg/m^3.

Following the initial blast a number of open joints, generally trending NNE, were observed, particularly in the NW batter with one open joint later found 21m behind the batter. The batters were progressively geologically mapped.

At RL 172m a sheared bedding plane was exposed with up to 100mm of grey or limonite stained silty clay infill. I noticed that many pre-split holes, which had been drilled across this plane, had off-sets of up to 150mm but generally 25 - 50mm. The sense of movement was that the upper block had moved back diagonally into the hillside.

Figure 7: Kangaroo Valley Power Station Excavation following the 'Big Bang'

A number of possible explanations were considered but after further mapping, monitoring and a number of joint inspections it was finally realised that the movement was probably due to the cratering effect caused by the "big bang", due to a not very effective pre-split line around the blast and the presence of the near horizontal, sheared bedding plane just above the base of the blast (Figures 7 and 8). This plane allowed gases from the blast to penetrate the pre-split and pass up the persistent, unfavourably oriented, weathered joints. Similar movement was reported to have occurred at Copeton Dam, also following a large blast (K. Crane; pers com).

Figure 8: KVPS Open joints in the bench above the 'Big Bang'

6 FITZROY CANAL

Fitzroy Canal runs from the Kangaroo Pipeline control structure to Fitzroy Falls reservoir. The canal is 4,200m long, has an invert width of 10m which rises from RL 648.2m to 657.4m. Its full supply level is RL 663.7m. The canal runs along the margin of a near flat-topped sandstone ridge on the western edge of the Robertson Plateau. To the west the ridge is bounded by an almost continuous sandstone cliff over 100m high. Above this main cliff line there is a series of smaller cliffs with the base of the upper line of cliffs generally lower than the canal invert level. In places these low cliffs approach to within 70m of the canal.

The canal has been excavated through sandstone, siltstone and mudstone of the Triassic aged Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone. The area is intruded by a swarm of basaltic diatremes (volcanic necks) and dykes with the canal cutting through three diatremes and 13 dykes (see Figure 9). There was one section where the Hawkesbury Sandstone was extremely friable for the full depth of the canal. The ubiquitous, steeply dipping, NNE and ESE trending joint sets are present with joints occurring in zones of up to 10 joints spaced 0.5 to 4m, with zones spaced 1m to over 30m. Most of the joints within the canal were limonite stained with some open up to 5mm. There was also a series of minor, steeply dipping normal faults, mainly running parallel to both joint sets with throws of 50 to 600mm.

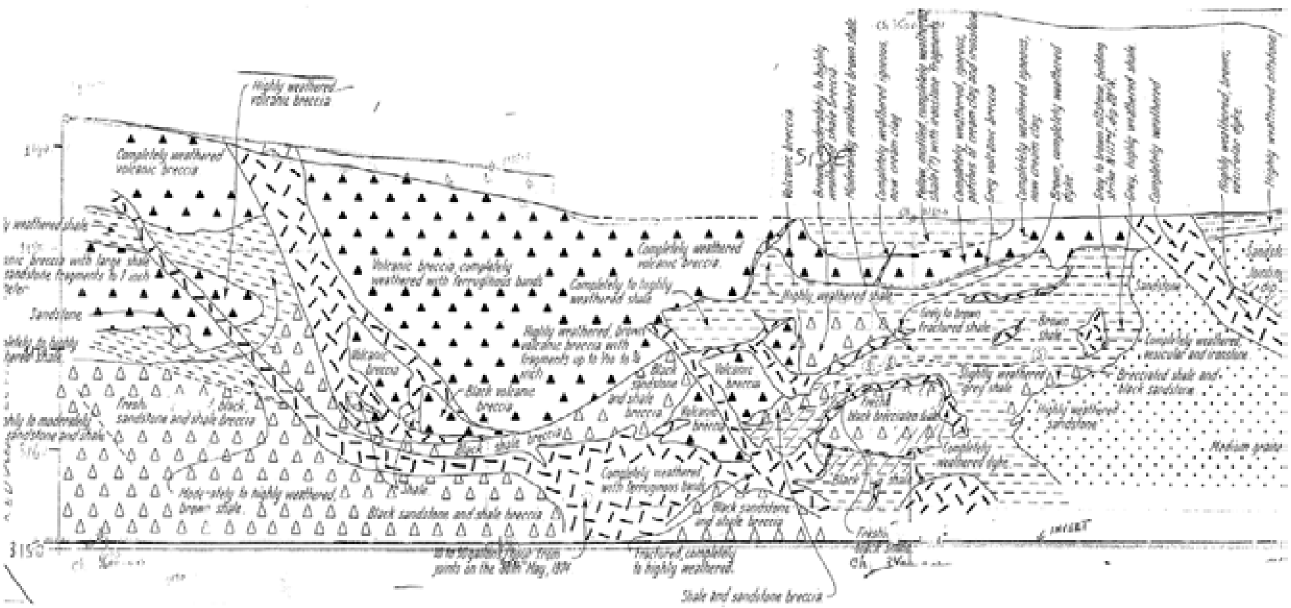

Figure 9: Fitzroy Canal – log of diatreme exposed on batter

7 LARGE SCALE LEAKAGE TEST

Site investigation included the drilling of 14 vertical boreholes along and to below the canal invert together with another five nearby. All holes were water-pressure tested with a total of 69 tests, with leakage values ranging from less than 1 to 65 lugeons. The arithmetic mean leakage value in the Mittagong Formation was 8.7 lugeons while that in the Hawkesbury Sandstone was 6.5 lugeons. Groundwater measurements were made at irregular intervals over a period of 16 months prior to the start of canal excavation. In general, the water table was below canal invert over the first 1500m of the canal from the Kangaroo Pipeline control structure. Beyond 1500m the water table was generally above canal invert level, in places rising to above full supply level.

From the water-pressure testing and the groundwater monitoring only minor leakage from the canal was anticipated, mainly from the first 1500m of the canal. Provision was made in the Bill of Quantities for limited shotcreting of about half the canal's surface between Chainage 0 and 1500m to cover open joints, bedding planes and other potential leakage paths, with the resident engineering geologist to initially nominate the features to be covered.

While I was grappling with the dilemma of how to identify which zones should be identified for shotcrete treatment I noticed that the level of water ponding within different excavated sections of the canal, after each rainfall event, was consistently dropping at a rate of approximately one to three inches per day. As leakage would not affect the stability or safety of the canal, the only cost incurred by the leakage would be the additional cost of pumping replacement water up from Lake Yarrunga below. This prompted the question, how much water loss replacement, using the capitalised cost of pumping, would justify covering the canal invert and sides with a mean thickness of 75mm of shotcrete. The answer was 9,250 litres/minute, much higher than what was being measured.

To check on the apparent leakage rate, the trial quarry, which had been excavated on the canal centre line at Chainage 793, was filled with water. The steady-state water loss was 60mm per day, about 20 - 25% of the amount that would justify treatment. As the canal was not on the critical path, the next stage was to carry out a full-scale leakage test once excavation of the canal had been completed. The long term water loss was 46mm/day, 1,700 litres/minute which justified not treating the canal (see Braybrooke, 1988). Note this is equivalent to 6.7 litres/second/kilometre. Taking the mean lugeon value for the canal of 6.5 lugeons and treating the water loss as a very large scale lugeon test with the pressure head equal to half the depth of water in the canal, the calculated water loss would be 1500 litre/minute, virtually the same as that measured. This is a relatively crude but quick method of estimating water inflow or outflow to tunnels, shafts and dams that I have been using ever since.

8 FRIABLE SANDSTONE

A low ridge between Chainages 3505 and 3688m comprised friable, weakly cemented sandstone to the full depth of the canal. The sandstone could be readily crushed by hand. As concern had been raised about the side-wall stability of a 2Horizontal : 1Vertical slope when under water, a series of tests were carried out on samples.

Thin sections were cut and petrographically compared with non-friable sandstone. The difference between the two was that the friable sandstone was more poorly sorted and contained a significant amount of clay in the matrix such that many of the smaller quartz grains were surrounded by clay with no fusing of adjacent grains. The conclusion was that the friable properties appeared to be due to the sedimentation process rather than any secondary processes.

Tests on undisturbed samples gave the following results:

Direct shear	c = 179 kPa	phi = 42.8^0
Saturated drained triaxial	c = 252 kPa	phi = 51.4^0
Dry density	2.032 t/m^3	
Moisture content	6.9%	

Slip circle analysis for the rapid draw-down condition, even with earthquake conditions using the above parameters gave factors of safety of greater than 3. In other words side-wall stability was acceptable and the face was left as-is and was protected by Hawkesbury Sandstone rip-rap.

9 SANDSTONE AS RIP-RAP

Hawkesbury Sandstone rip-rap was also used on Fitzroy and Wingecarribee Dams while Nowra Sandstone rip-rap was used on Bendeela Pondage. Some years later, after I had joined the Electricity Commission of NSW, a question came up about sources of rip-rap for dams around Bayswater Power Station. As sandstone appeared to be the most economical, won from coal-mine overburden, I instituted a research programme in the early 1980s into the use of various tests, including sodium sulphate testing, as acceptance tests.

This required sampling previous sandstone rip-rap that had been successfully used on the Shoalhaven Dams and various breakwaters near Newcastle, testing material that appeared to be performing well as opposed to material that was relatively rapidly breaking down. The results indicated that sandstone with less than 30% loss was acceptable but sandstone with more than 30% loss broke down relatively rapidly. These results closely paralleled the conclusions from similar research by MacGregor (1982) investigating acceptable rip-rap sources for marine breakwaters.

10 WINGECARIBEE DAM

Wingecarribee Dam is a 19m high earth and random fill dam constructed from residual soil and rock derived from Ashfield Shale and is founded on the Ashfield Shale residual soil profile. As an alternative, suggested by the successful tenderer, Abignano, the filter zone largely comprised crushed Hawkesbury Sandstone derived from a section of Fitzroy Canal. One igneous dyke runs through the foundation with two others running through the spillway structure. The shale on either side of the dyke through the foundation was closely fractured parallel to the dyke. Grouting of this fractured zone was unsuccessful due to the low grout pressures that had to be used. To protect the dam body from potential piping a concrete culvert structure was constructed over the dyke and fractured zone.

Some concern had been expressed about the potential breakdown of fresh shale fragments within the random fill shoulders. Similar concerns had also been expressed during the design and construction of Prospect Dam in Sydney and for a number of dams in England. In both Sydney cases these concerns were allayed, firstly by the demonstration that underwater, fresh shale fragments remained fully intact and then by trial excavation into shale embankments which exposed fully intact shale fragments showing no sign of fretting or breakdown.

During construction of the embankment the river was kept within its original channel until the spillway structure and outlet works had been constructed. The river was then relocated to run through the outlet works and its original channel prepared for embankment construction. This required marrying the new section of embankment to the previously constructed left abutment. To do this the filter zone was exposed and cleaned up while the clay core was cut back to remove any softened material, tyned and re-compacted with a sheeps-foot roller, the new embankment being married into the re-compacted zone. Again concern was expressed about the water-tightness of this re-compacted zone. To investigate the zone, a series of holes were drilled through it and inspected by way of a video camera with the video being subject to close review by various dam embankment experts including J Barry Cooke, an international expert on dam construction, used by both SMEC and the Sydney Water Board. The re-compacted zone was deemed to be successful which later on was confirmed once the dam was completely filled.

One glitch during drilling of the dam embankment with the dam two-thirds full was the use of a percussion rig. One evening, as I was passing the dam after inspecting some of the downstream works in Kangaroo Valley, I noticed a drill rig on the dam wall. Not being told that it had been decided to drill the wall to inspect the integrity of the re-compacted zone I was curious and concerned. As I walked onto the dam wall I suddenly saw an eruption of brown water within the lake, adjacent to the dam wall. The drill rig had been drilling with compressed air. The air - soil return must have built up on the drill stem, blocking the return air, forcing it to find another escape route; into the lake. Drilling was terminated immediately and another drilling method used. However, no damage appeared to have been done to the embankment wall.

Only finger drains had been designed as outlets from the chimney drain. On dam filling these proved to be not capable of fully handling the seepage, and pore pressures started building up in the downstream toe of the dam. This was handled by judicious re-excavation of the dam toe to install a downstream blanket drain below the highest section of the dam.

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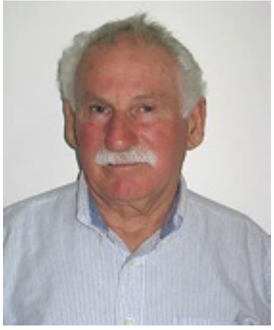
THE DEVELOPMENT OF ROCK MECHANICS FOR UNDERGROUND POWER STATIONS IN TASMANIA



TOM BOWLING

Tom Bowling is a specialist geotechnical consultant with Entura, the engineering consulting section of Hydro Tasmania. He has degrees in Science (maths and physics) and civil engineering from the University of Sydney. After graduation he worked for five years on the Snowy Mountains Hydro-Electric Scheme in Cooma. In 1966 Tom moved to the Tasmanian Hydro-Electric Commission where he stayed for 31 years, working on the construction of a 40m high arch dam on the Derwent River, in structural model testing, design and regular site inspections for underground works. In 1997 he took early retirement and returned to Hydro Tasmania as a casual geotechnical consultant.

After the Second World War the Tasmanian Government, through the Tasmanian Hydro-Electric Commission, commenced the development of the state's hydro-electric potential beyond the Waddamana and Tarraleah schemes that had been constructed between the two world wars. These new developments finally extended for over forty years to the completion of the Anthony Power Development on Tasmania's west coast in 1994. These power schemes included the investigation, design and construction of four underground power stations.

This period after the Second World War was a time when rock mechanics was becoming recognised as an important facet of civil engineering and in the late 1960s it was combined with soil mechanics and engineering geology into the new discipline of geotechnical engineering. In constructing these underground power stations the Commission's engineers and geologists used the latest developments in rock mechanics and also contributed their own experiences (and techniques) to this new field of civil engineering.

The first of these underground power stations, and perhaps the most significant from a geotechnical point of view, was part of the Poatina Power Development. This development involved the diversion of water from Tasmania's Great Lake in the central highlands to the underground power station located 150m below the foot of the Great Western Tiers. The underground chamber is 91m long, 26m high and 14m wide and houses six 50MW generators. The chamber is located in horizontally bedded Permian mudstones. Design of the power station chamber commenced in the late 1950s, with excavation starting towards the end of 1960 and being completed by the end of 1962. The power station was officially opened in 1965.

The lead designer for the power station was Mr Lance Endersbee who pioneered a number of rock mechanics ideas in the design. The implementation of these ideas in the design and subsequent excavation of the power station chamber was detailed in a landmark, and often cited, technical paper in 1963 (Endersbee & Hofto, 1963). Mr Endersbee was involved in setting up the Tasmanian Group of the Australian National Society for Soil Mechanics and Foundation Engineering, the forerunner of the Australian Geomechanics Society, in 1964. He was vice-president of the International Society for Rock Mechanics from 1966 to 1970.

One of the main aims of the design of the Poatina chamber was to obtain a stable and self-supporting roof shape without having to use a permanent concrete arch structure. Although rock bolts were coming to be used for rock support in unlined underground works it had been noted in the access tunnel to the Poatina underground site that the horizontally bedded rock tended to spall to a trapezoidal shape in the nominally circular tunnel roof. After exploratory excavations were carried out to confirm this tendency it was decided to adopt a trapezoidal roof shape for the main power station chamber. A suitable angle for the sloping sections of the trapezoidal roof was obtained from the angle of shear resistance on bedding planes in the rock deduced from triaxial strength tests on rock core specimens.

The designers then considered the possibility of rock failure in the walls and particularly in the roof of the main chamber due to the concentration of the natural rock stresses at the site. At this time such natural rock stresses were commonly assessed by considering a simple confined elastic rock medium under self-weight while stress concentrations were determined from mathematical solutions for stresses around holes of simple shape in elastic bodies. However observations during exploratory excavations at the site suggested that natural rock stresses might be higher than those assessed by elastic self-weight theory. A series of insitu measurements to determine the natural rock stress conditions at the Poatina site were therefore undertaken in the access tunnels at the site using the flat jack method of slot displacement cancellation.

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This method had been developed by the French engineer M E Tincelin in the iron ore mines of France and had been further developed by L G Alexander (Alexander 1960) in the Snowy Mountains Hydro Electric Scheme where two underground power stations were being constructed at this time.

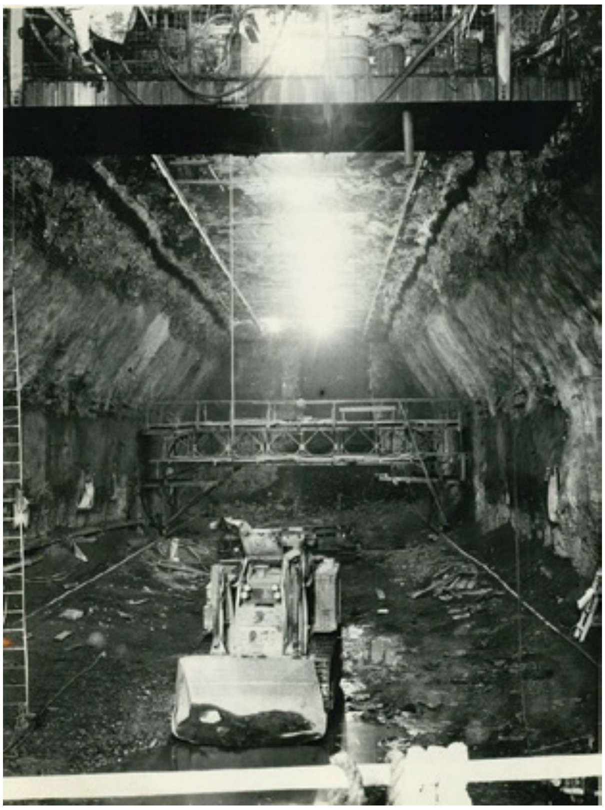

Figure 1: Poatina underground power station during excavation

The deduced natural rock stress conditions at Poatina were found to be much higher than those obtained from the simple elastic self-weight approach. However at this time underground rock stress conditions were increasingly being measured around the world (Hast 1958) and it was becoming evident that horizontal rock stresses were often equal to or greater than the vertical gravity rock stress, which was the situation that had been found at Poatina. It appears that the vertical rock stress at Poatina had also been increased topographically by the nearby Great Western Tiers rising to 1100m above the chamber level.

To determine what stress concentrations in the rock around the power station chamber might develop due to the high natural rock stress conditions it was realised that the simple mathematical solutions would only give partial answers. At this time the sophisticated computer methods of stress analysis now available to a designer had not been developed and it was decided to carry out a series of photo-elastic model stress investigations in collaboration with the Snowy Mountains Hydro Electric Authority. At this time the Authority had a photo-elastic laboratory, run by Mr George Worotnicki, in its Scientific Services Division in Cooma. This laboratory had been carrying out investigations in connection with the design of the Authority's two underground power stations in the Tumut River development. The photo-elastic investigations for Poatina indicated potential rock failure due to significant stress concentrations in the two corners of the trapezoidal roof. These stress concentrations would increase as the chamber was excavated down from the initial roof cavity excavation.

It was therefore decided by Endersbee that stress relieving slots should be cut along the two corners in the roof at the initial stages of excavation which would also relieve high compressions in the immediate flat section of the roof. The slots were achieved by drilling a line of almost over lapping diamond drill holes 1m deep into the two corners of the roof. During excavation of the chamber down from the roof cavity the stress conditions and dilations in the flat section of the roof were monitored using flat jacks grouted into the roof as stress meters and by using 4.3m long rock bolts as dilation meters. Closure of the slots was also monitored and was controlled initially by driving wooden dowels into alternate drill holes in the slots and finally, when specified compressive stresses had been measured in the roof, by filling the alternate slot holes with quick setting mortar.

Another rock mechanics aspect of the excavated chamber was the inwards creep movement of the two long vertical walls due to stress relaxation in the rock. This was monitored with 15m and 32m long rock bolts used as dilation meters set horizontally at mid-height into the two walls. As this creep movement appeared likely to continue, though at a diminishing rate, after the completion of the power station, the design was modified to incorporate a sliding joint in the bottom concrete floor of the station. Movements on this sliding joint were monitored for two or three years after the station was completed by which time movements had become negligible.

An important aspect of the Poatina project was the cooperation that was achieved between the designers and the construction personnel in monitoring conditions as excavation progressed, the use of various instruments to carry out this monitoring, and the implementation of design changes to accommodate features that developed that could impinge on the successful completion of a stable underground chamber.

Figure 2: The completed Poatina underground power station

The rock mechanics experience that had been obtained in the construction of the Poatina underground power station was used and further developed in the design and construction of the Hydro Electric Commission's three other underground power stations. These were the Cethana power station located in the north of the state, Gordon power station in the south-west and Tribute power station in the Anthony scheme on the west coast of Tasmania.

At all three stations the power station chamber was excavated in competent igneous or metamorphic rocks and conventional circular arch roofs where pattern rock bolting support could be used. At Gordon and Tribute power stations more sophisticated methods of natural rock stress measurement were used and finite element analysis was available to the designer to refine the chamber shape and design rock support. Other rock mechanics developments employed on these stations was the use of rock bolts with better anchorage and grouting features and the use of fibre reinforced shotcrete rather than shotcrete with mesh reinforcement.

At Gordon a novel geotechnical feature was the use of pre-compression grouting of the concrete lining of the inlet distributor tunnel for the turbines (Olive, 1976). The induced compression in the lining off-sets the water pressure induced tensions in the lining thus avoiding the need for a water-proof steel lining. This method had been developed in Europe and was known as Lauffer Grouting. In the early 1970s this was the first use of the method outside Europe and the largest diameter pressure tunnel, at 8.23m internal diameter, in which the method had been used.

In 1969 a two week Vacation School in Rock Mechanics was held at the University College of Townsville. Amongst the invited lecturers at this School were Mr Lance Endersbee, Mr George Worotnicki and Professor O C Zienkiewicz from the University of Wales. Professor Zienkiewicz described the newly developed finite element method of stress analysis, of which he was one of the principal developers and the co-author of one of the first text books on the topic (Zienkiewicz and Cheung, 1967). The finite element method would come to replace the photo-elastic and other experimental methods of stress analysis for design work. Mr Worotnicki, after leaving the Snowy Mountains Authority, continued his rock mechanics work with the CSIRO's Division of Geomechanics in Melbourne. Mr Endersbee became Dean of Engineering at Monash University in Melbourne and finally Pro-vice-Chancellor of this university before his retirement.

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DR BILL BAMFORD CHAIR 1976-78

When I commenced my engineering career in the middle of last century there was a saying that "An engineer can accomplish with 1 pound (dollar) what any other fool can do with 2". Nowadays most of that engineer's dollar would be absorbed by administration, compliance and union disputes, so society gets much less "bang for its buck" than it used to.

1 JOHN JAEGER AND HIS MEMORIAL AWARD

In 1959, while working as an Engineering Geologist for the Snowy Mountains Hydro-Electric Authority, investigating the pressure tunnel alignment between Geehi dam site and the M6 underground power station site, I took Professor Jaeger's team of heat flow measurers from the Australian National University to some of the deep exploratory diamond drill holes on Broken Back Spur, above Khancoban, and assisted them with their measurements.

In 1967, after I had been appointed the inaugural Lecturer in Rock Mechanics at the University of Melbourne, Professor Jaeger invited me to spend some time with him at the Australian National University, to discuss my development of teaching and research in rock mechanics.

I had useful and interesting discussion with John Jaeger, his colleagues Mervyn Paterson and Ted Ringwood, and his postgrad students Kevin Rosengren and Earl Hoskins.

At the 1st Congress of the ISRM in Lisbon in 1966 Lance Endersbee was nominated as the inaugural Vice-President representing the Australasian region. At the conclusion of his term, at the 2nd Congress in Belgrade in 1970, Professor John Jaeger was nominated to be his successor. Ill health prevented him attending that Congress, or any of the successive annual Board and Council meetings. After 1972 Dr Alan Hargreaves was appointed for the remainder of his term to 1974, and then for a full term in his own right until 1979.

Meanwhile I had become Chairman of the AGS national committee in 1975. We became concerned when all notices and committee papers sent to Professor Jaeger at his remote retirement house about 23km from Port Arthur on the Tasman Peninsula in Tasmania were returned to us uncollected : the house was too remote for mail deliveries and his failing health, and that of his wife, meant that they could not travel in to Port Arthur to collect their mail.

When he eventually died in May 1979 I had already been delegated to suitably memorialise him. I remembered the high pressure triaxial tests on Wombeyan Marble which I had watched while visiting his lab in 1967 and decided to be inspired by that shape and material.

This is a photo of one of their test specimens, exhibiting the characteristic failure plane making an angle of 30° to the core axis.

Two distinguished alumni of the University of Melbourne, Roy Hardcastle and Harold Richards, had gone into partnership as Hardcastle & Richards in 1952, and 25 years later decided to celebrate their anniversary to make a gift to the Melbourne School of Engineering. Professor Len Stevens suggested that it should take the form of a sculpture with an engineering theme, to be mounted on the face of the Civil Engineering building, and eminent young sculptor Michael Meszaros was commissioned. (Incidentally his father Andor Meszaros had designed and cast all the medals awarded at the 1956 Melbourne Olympiad.) Len Stevens and Michael Meszaros came up with the following design, which was installed in 1979.

Tension and Compression
Melbourne School of Engineering
Cast Bronze 1.5m x 1.5m, 1979.

With this as inspiration, Michael and I then came up with the following design, reflecting man overcoming earthen and underground forces.

I found it impractical to perfectly mimic the Wombeyan marble triaxial test specimen, by cutting an oblique plane at 30° to the axis, as the sharp edge tended to break off under slight pressure, so the plane on this and all successive specimens was cut at 45° to the core axis.

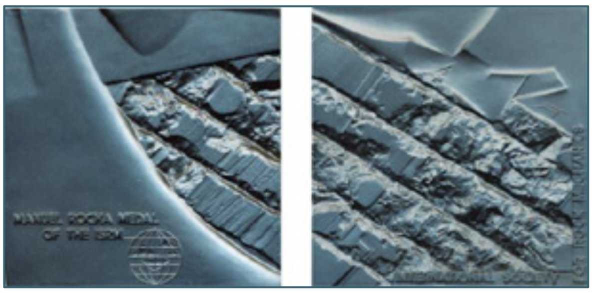
The Committee decided that the John Jaeger Memorial Award would be presented at each quadrennial Australia-New Zealand Conference on Geomechanics, with the first presentation to take place in Wellington, New Zealand, in May 1980. The inaugural recipient was selected to be Professor Ted Davis.

Manuel Rocha, the President of the ISRM from 1966 to 1970, died in 1981.

By now I was the Vice-President of the ISRM representing the Australasian region, so when I attended the annual Board meeting at which Professor Rocha's memorial was discussed I tabled a photograph of the John Jaeger Award medal, which the Board passed on to the Portuguese sculptor who was going to be commissioned to design the Rocha Award.

I like to think that some of Michael Meszaros' vision is reflected in the Rocha medal.

I believe that it is symbolic of a dam founded on inclined rock strata – Manuel Rocha was a distinguished dam designer.



2 THE AUSTRALIAN TUNNELLING ASSOCIATION AND THE AUSTRALIAN GEOMECHANICS SOCIETY

In 1970 the AusIMM held its annual conference in Melbourne. There had not yet been a conference on mechanized tunnelling in Australia, but there was at the time a significant amount of such tunnelling taking place in and around Melbourne. So I was given the go-ahead to organize a separate but contiguous specialized Symposium on Raise and Tunnel Boring in Australia, held in the Public Lecture Theatre at the University of Melbourne, immediately after the main AusIMM Conference in the city of Melbourne. 19 papers were presented, to an audience numbering 202. A full day of visits to mechanized tunnelling activities on the South-East Trunk Sewer and the Dandenong Valley Trunk Sewer took place the next day.

This symposium was retrospectively recognized as the "First Australian Tunnelling Conference", and I believe that its success led to the AusIMM nominating me to be their representative on the national committee of the Australian Geomechanics Society from the time that it was formed in 1971 onwards.

I was a member of the organizing committee for the 1st Australia-New Zealand conference on Geomechanics, held in Melbourne in 1971, and presented 2 papers (on the prediction and measurement of the long-term strength of rock, and on stresses induced by mining operations at Mount Charlotte Mine).

When the body which eventually became the Australian Tunnelling Society was formed in 1972 it was under the auspices of the Australian Geomechanics Society, and its founding statutes stated that the chairman of the new tunnelling body "should be the Chairman of the Australian Geomechanics Society, or his nominee".

When I assumed the position of national chairman of the Australian Geomechanics Society in 1975 I unsuccessfully tried to find a suitable nominee to be chairman of the tunnellers, and eventually took the job myself. During my 3 years as chairman of both societies I probably spent more effort on getting the Tunnelling society established than on continuing the already well-established Geomechanics Society. In 1974 the IEAust organized a seminar in Melbourne on "Re-Shaping Cities Using Underground Construction", with 14 invited papers from mainly overseas planners. We decided that a "conventional" tunnelling conference, with Call for Papers, refereeing, etc. should be our next priority, in 1976. The Organizing Committee comprised Bob Horseman, Charles Gerrard, Warren Peck, Frank Watson and myself as Chairman. 21 papers were presented, and the success of this Conference established a regular series of successors, at 2 or 3-yearly intervals.

I continued to be a member of the National Committee of the AGS from 1971 until 1987, was a member of the Victoria Chapter committee from 1968 until 2002, and served as Victoria chairman for 3 terms, in the mid-70s, the mid-80s, and the mid-90s.

I served as a member of the national committee of the Australian Tunnelling Society and its predecessors from 1975 until 2002, and on the Victoria Chapter committee from 2011 until 2015.

In 1997 the AGS proposed a new venture to unite the major international geotechnical societies, at an International Conference on Geotechnical and Geological Engineering, to be held in Melbourne Australia in November 2000. The sponsoring bodies were the ISRM, the IAEG, and the ISSMFE. I was invited to join the organizing committee, and travelled to Singapore with other committee members, including chairman Max Ervin, to make the final pitch to the 3 international socieites, which resulted in us getting the green light, I was also given responsibility for organizing the "Underground Works" stream, and getting the papers refereed by an eminent international panel.

3 THE INTERNATIONAL SOCIETY FOR ROCK MECHANICS (ISRM)

After my term as national chairman of the AGS ended, the national committee nominated me to succeed Alan Hargreaves as the Australasian regional Vice-President of the ISRM, to take office at the 1979 Congress in Montreux Switzerland. The Committee also decided to make a bid to host the next scheduled Congress in 1983, and gave me the responsibility of organizing and presenting the bid. When I presented Australia's bid to the Congress it was accepted, and then I was appointed as chairman of the organizing committee. This made for a very busy next 4 years. As well as continuing with a full teaching load at the University of Melbourne, writing my PhD thesis (which was finally successful in 1983), planning the 1983 Congress, and representing the Australasian region in ISRM Board and Council business, I was active in the Commissions. I was an active contributor to the Commission on Testing Methods and Commission on the Teaching of Rock Mechanics; I also proposed, and was the founding President of, the Commission on Swelling Rocks, and the Commission on Rock Boreability Cuttability & Drillability.

At the 1987 ISRM Congress in Montreal I acted as chairman for the session on "Deep Excavations" and organized an open session on Rock Boreability Cuttability and Drillability.

I find it interesting to note the strong Melbourne flavour in ISRM representation.

Our inaugural regional Vice-President, Lance Endersbee, was a civil engineering graduate of the University of Melbourne. After John Jaeger's term, truncated by illness, Australia was represented by Alan Hargreaves, a mining engineering graduate of the University of Melbourne, and then myself, who taught in the mining and civil engineering departments of the University of Melbourne. I was succeeded by Ian Johnston, from the civil engineering department of Monash University in Melbourne. Also, in 1983 Ted Brown, a civil engineering graduate of the University of Melbourne, became the ISRM President.

After 1983 it became New Zealand's term to nominate the regional Vice-President, but they did me the unprecedented great honour of asking me to accept re-appointment as their representative. Here are a few snapshots of me in action internationally on Australia's behalf.

Bill Bamford (& interpreter) speaking to the Japan Rock Mechanics Association. Tokyo 1981

Walter Wittke (ISRM President 1983-1987), Bill Bamford (V-P Australasia), Pierre Habib (ISRM President (1979-1983) at ISRM Board meeting in Aachen 1982

Bill Bamford (V-P Australasia), Sten Bjurstrom (V-P Europe), Arnaldo Silveiro (Secretary-General), Pierre Habib (President), at ISRM Board meeting in Aachen 1982

Ted Brown (President), Nuno Grossmann (Secretary-General), Bill Bamford (V-P Australasia) at ISRM Board meeting, Zacatecas Mexico 1985

4 RETURN TO UNIVERSITY OF MELBOURNE DUTIES

Shortly after my period of greatest engagement with the ISRM ended, after the 1987 Congress in Montreal, I was asked by the Dean of Engineering to accept a transfer to work directly with him in the Faculty Office, in the position of Director of First-Year Studies. A couple of years later I was concurrently appointed to be Associate Dean – Academic.

During these 5 years I continued with a full undergraduate teaching load, plus postgraduate supervision. Also for this period, and for the following decade, my rock mechanics lab generated about half of all the external consulting revenue earned by the Melbourne School of Engineering.

In 1996 I was declared "redundant", but was allowed to keep the titles of Principal Fellow & Associate Professor, remain in my office, keep running the rock mechanics lab, and undertake a partial teaching load.

In 2011 I was appointed a Senior Principal by Coffey Testing, and transferred my lab from the University of Melbourne, with the aim of developing a world-class joint Coffey-UniMelb rock testing lab.

In 2014 I left Coffey and established my private rock testing facility, which is keeping me busy during my desuetude.

My appointments with the University of Melbourne continue.

5 INTERNATIONAL TUNNELLING ASSOCIATION

I was a member of the organizing committee for the World Tunnel Congress which was held in Melbourne in 1987, and participated as co-Chairman of the Working Group on "prediction of tunnel machine performance".

When my heavy administrative commitments to the Melbourne School of Engineering reduced in 1994 I was able to resume travelling on technical society business, so from 1994 until 1999 I represented Australia at the annual meetings of the International Tunnelling Association and the World Tunnel Congresses. At the Oslo meeting in 1999 I presented Australia's bid to host the World Tunnel Congress in 2002, which only just defeated Singapore's rival bid, vigorously presented by Jian Zhao, who is now resident at Melbourne's Monash University.

6 SOME CHANGES I HAVE NOTICED

In 1957 when I went to work on the Snowy Mountains Scheme there was, throughout the tunnelling industry, an expectation and acceptance that there would be a death rate of at least 1 per mile of tunnel. The Scheme was completed on time and on budget, with 121 people killed, for the 140 miles of tunnel – a "world's best" result. Nowadays a tenth of that death rate could lead to a Royal Commission enquiry; and no major projects finish "on time and on budget"!

When I worked at Mount Isa Mines in 1974-5 I was impressed by the unions' response to any workplace fatality – they went on strike and stopped production for as many hours as it would take for the cost, to the Company, of the lost production of the minerals to equal the actuarial insured cost of 1 life, to the insurers. In this way the Company was immediately penalized, and was thereby incentivised to immediately improve workplace safety. Nowadays it can take years for a Coroner's Court case to be successfully mounted against an employer, and any fines imposed have little deterrent effect, and are merely extra revenue for the government.

ARTS CENTRE MELBOURNE GEOTECHNICAL ISSUES

DR JACK MORGAN

Jack Morgan is an unsung hero of geotechnical engineering in Melbourne. He graduated from the University of Melbourne with a Bachelor (and Dux) of Civil Engineering in 1957, followed by a PhD, also from UM.

After 3 years as senior engineer with the Department of Works Jack took up a position as Senior Research Fellow, later Senior Lecturer, with the University of Melbourne, where he remained for 12 years, leaving in 1975 as Reader in charge of soil mechanics.

In 1975 Jack moved into consulting as a Principal with Golder Associates. He retired from full time consulting in 1997, but remained as a Senior Consultant with Golder until 2016. Jack pioneered work on deep basements in the Coode Island Silt of the Melbourne area.

1 THE THEATRES BUILDING

The Theatres Building of Arts Centre Melbourne is made up of three auditoria - the State Theatre (capacity 2000), the Playhouse (capacity 900) and the Fairfax Theatre (capacity 450). This paper describes some aspects of the geotechnical investigations, design and construction of the building over the period 1969 to about 1978. The Theatres Building was completed in 1984. The photo below shows the Theatres Building on St Kilda Road located between the National Gallery of Victoria and Hamer Hall (formerly known as the Concert Hall).

The geotechnical challenges of the project arose from the combination of poor ground conditions at the site and the desire to construct the major theatres below ground level. Of the 12 principal levels, seven are below the street level on the St Kilda Road boundary.

2 THE SITE

The main features of the subsurface conditions are the presence of up to 17m thickness of the highly compressible clays of the Coode Island Silt Formation overlying the sands and gravels of the Moray Street Gravel Formation.

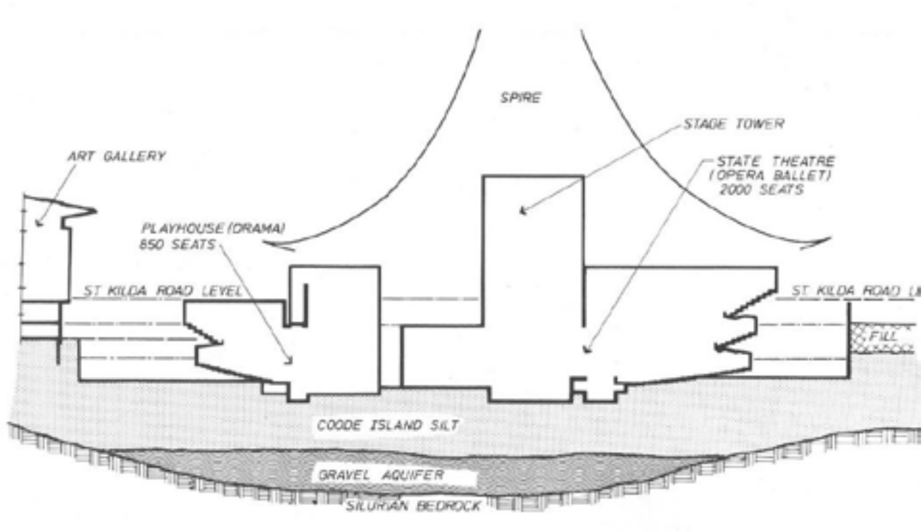


Figure 1: Longitudinal section through Theatres Building

The Silurian Age siltstones and mudstones (the Melbourne Mudstone) form the bedrock of the area and occur at depths of about 20 m to 25 m.

Figure 1 is a longitudinal section through the site showing the subsurface conditions and also some features of the temporary and permanent construction, as finally adopted.

The upper surface of the Coode Island Silt is at about RL0 which is also about the level of the ground water table. Blanketing the Coode Island Silt is a layer of variable fill from about 4m to 8m in thickness, resulting in a fall in ground surface level over the site of about 4m, the St Kilda Road boundary being the highest.

The properties of the Coode Island Silt have been discussed by Ervin (1992). Of particular interest here is its settlement behaviour. Moore and Spencer (1969) traced the settlement history of a building constructed in similar ground conditions in 1890 which by 1965 had settled about 790mm.

Observations of settlements of some buildings in the South Melbourne area over the period 1890 to 1990 were collected as part of the preliminary investigation. These showed total settlements over that period in the range 650mm to 800mm. These buildings are all light structures so it was inferred that the settlements resulted from regional effects rather than from building loads.

In 1969 no permanent basements had been constructed in the Coode Island Silt to below the water table, and it was clear that there would be many challenges in constructing a major basement structure to accommodate the Theatres Building.

3 STUDIES IN 1969-1970

3.1 The Structure

In 1969, planning was proceeding on the basis of accommodating three theatres and a concert hall on the subject site. Subsequently the concert hall (Hamer Hall) was constructed on an adjoining site thus reducing the amount of subsurface space required to house the three theatres.

The challenge of the 1969 project was to construct a below-ground space to house the massive auditoria. By their size and arrangement the auditoria limited the use of simple cross-site struts to transfer the large earth and water pressures developed on the basement walls.

The solution proposed for the construction stage was a massive perimeter retaining wall spanning between a strutting frame at the top and the mudstone at the bottom. The wall types investigated included interlocking caissons and solid or cellular walls. Construction expedients considered included the use of ground freezing, pressure grouting and construction under bentonite slurries.

3.2 The Investigation

It was clear that there would have to be a significant geotechnical investigation program to provide the data required for analysis of the basement wall.

The investigation was planned by Milton Johnson and Associates in association with the writer, to the requirements of the civil and structural consultants, John Connell & Associates. It was notable for the wide range of field and laboratory testing techniques performed.

Drilling and Sampling: Thirteen boreholes were drilled around the perimeter, extending about 13 m into the mudstone. Tube samples of 4½ inch (114 mm) diameter were recovered rom the Coode Island Silt, and rock core of 5½ inch (14 mm) diameter from the mudstone.

A downhole television camera was used to observe the orientation of the joint features in the mudstone.

Laboratory Testing: Conventional classification, drained and undrained strength testing was performed on samples of the Coode Island Silt. Tests to estimate the coefficient of earth pressure at rest were performed at Sydney University.

An extensive program of tests on frozen soil samples was also performed to assist in assessing the viability of ground freezing during construction of the perimeter wall. These included compressive and tensile strength and creep tests on frozen samples at a range of temperatures as well as tests on frozen then thawed samples.

Field Tests – Rock: A 1750 mm diameter steel lined caisson was sunk to the mudstone. Below this, a chamber about 3.4 m in diameter was excavated to allow shear strength tests on discontinuities in the rock mass to be performed and to provide opportunity for the rock conditions to be inspected by potential tenderers for wall construction.

Field Tests – Soil: A second caisson was sunk to provide access for installation of earth pressure measuring cells with accompanying piezometers.

This caisson was also used to permit a pump test to be carried out in the Moray Street Gravels aquifer to help assess its hydraulic characteristics.

4 STUDIES IN 1971-1978

4.1 The Structure

In 1970 the planning was changed to move the Concert Hall to the Snowden Gardens site north of the Theatres Building. This reduced the space required on the Theatres site so that it was possible to accommodate the three auditoria in a basement extending to a maximum depth of about 15m below the St Kilda Road level.

Figure 1 shows a simplified section through the Theatres Building indicating the arrangement of the auditoria and a simplified indication of the subsurface conditions.

While this approach might at first sight seem to be simpler than to construct the full depth basement, in fact the geotechnical and structural problems were far more challenging. The approach to basement construction developed by John Connell & Associates is shown in Figure 2. This took into account the need to provide support to the surrounding area without the use of cross-site struts while excavation of the Coode Island Silt took place inside the site.

The permanent perimeter wall and a part of the basement floor slab were constructed inside a strutted trench about 6.5m wide. Temporary tie-backs (rock anchors) were installed to take the earth and water pressures and allow the inner wall of the strutted trench to be removed and bulk excavation and floor construction to occur. Plate 2 shows the trench construction along the St Kilda Road boundary.

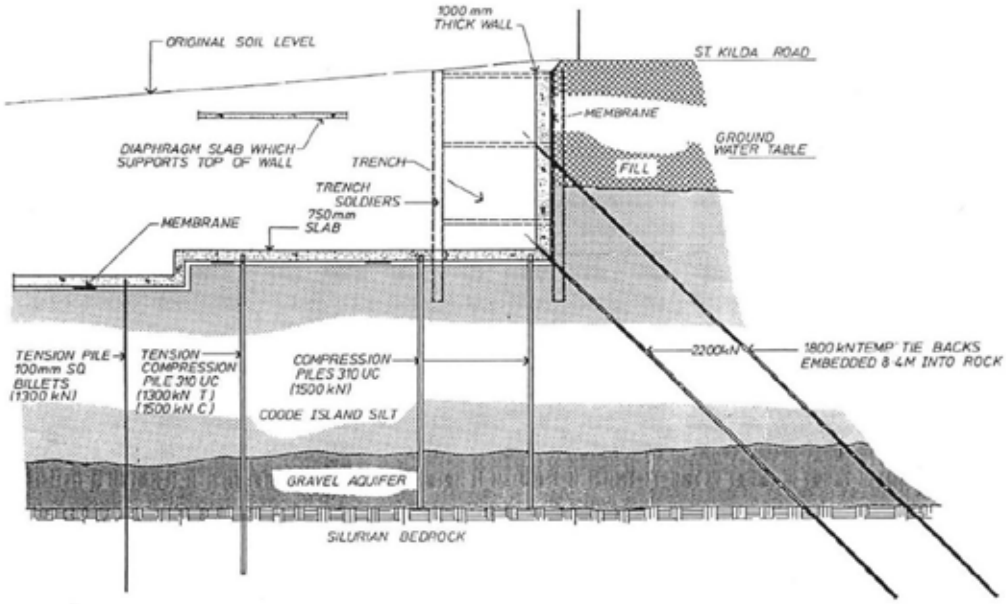


Figure 2: General Construction

Plate 2: Trench construction along St Kilda Road

Vertical loads applied to the foundation arose from the building weight and from buoyancy forces. Because of the large voids in the structure in some areas the buoyancy forces exceeded the building loads, necessitating the use of permanent tension piles. There are three types of piles, acting in compression, tension or initially in tension changing to compression as the building load was developed.

4.2 The Geotechnical Challenges

The site and method of construction presented particular geotechnical challenges. While the overall site conditions had been characterised by the 1969-1970 investigation, further work was needed to develop solutions. In addition, a ground and structure instrumentation program was initiated to measure the effects of construction and allow modifications to take place as and when required.

Trench Instrumentation

The behaviour of the trench was monitored to assess the loads acting, to ensure the design assumptions were not exceeded, and if possible to relax the requirements in the light of the measured values.

The instrumentation for this work comprised:

- Trench strut load measurement by DEMEC gauges
- Earth pressure and water pressure measurements by KYOWA boundary pressure transducers embedded in the concrete construction (outer) wall of the trench
- Inclinometers attached to the soldier piles on the inner wall of the trench
- Soil inclinometers comprising steel casing installed outside the wall and reading deviation using an optical plummet
- Piezometer installation.

Some results of these measurements are given in Morgan (1992).

Swell Instrumentation

Unloading of the Coode Island Silt during bulk excavation was predicted to result in swell. Laboratory testing and field measurements were used to predict the time-swell relationship.

The laboratory swell behaviour showed a significant creep component, not surprisingly, in view of the soil's known creep behaviour during compressive loading.

Field observations were made initially using downhole swell indicators installed in nine unlined boreholes inside the site. These devices used spring steel strips to anchor the sensors into the soil, but corrosion was so severe that they were replaced by sensors having a positive anchoring system.

Results of these analyses and measurements are given in Morgan and Walker (1977).

As a result of the observations and analyses, it was recommended that a 75mm void former be placed beneath the slab to accommodate the swell expected after the permanent floor construction had been completed.

Settlements

Settlements around the site were monitored from the start of construction. It was known that the Coode Island Silt was highly compressible and long-term observations of settlement in the surrounding areas had been documented. It was predicted that any significant reduction in groundwater level would increase the rate of long-term settlement.

The first indication of effects beyond the site was a fall in the observed levels in the piezometers outside the site, soon after installation of tiebacks commenced in 1975.

Over the period 1975-1978 considerable investigation was carried out into the extent of dewatering outside the site. The reduction in groundwater level was followed by an increased rate of settlement based on level observations on surrounding buildings and pavement surfaces. Recharge wells were installed which significantly reduced the extent of groundwater lowering, but did not totally prevent accelerated settlement continuing.

The reduction in groundwater levels beyond the site was inferred to result from horizontal flow through the Coode Island Silt. Examination of cores of the Coode Island Silt showed the presence of thin near-horizontal layers and partings of more permeable silt and fine sand giving it a high horizontal permeability, as described by Rowe (1972). Where these parting were intercepted by penetrations beneath and around the site (by piles and tiebacks) a path was created for significant groundwater flow.

Over the next few years the settlements continued and settlement damage occurred to a building located about 200m from the site. The damage there appeared to be related to the use of a mixed footing system of piles and surface footings. Adjoining buildings underwent similar total settlements but were undamaged.

The settlements effectively ceased when the site was finally sealed from groundwater inflow in May 1978. The groundwater levels around the site returned to their pre-construction values about two months later.

5 GROUNDWATER IN EXCAVATIONS

As a result of this experience, subsequent excavations in the Coode Island Silt have been designed addressing these characteristics where the excavations extended significantly below the groundwater table. These projects have usually included cut-off walls, monitoring of behaviour and recharge systems operating during the construction stage. Two examples are discussed below.

The Crown Casino was constructed on a site bordering the Yarra River and underlain by the Coode Island Silt Formation. The development needed to provide two levels of basement car park over the entire site. An innovative approach to groundwater control around the excavation was required to avoid depressurisation of adjoining soils, leading to settlements (Ervin and Morgan, 2001). Analysis showed a bentonite cut-off wall of normal permeability extending to bedrock would still allow depressurisation by lateral flow through the Coode Island Silt (and through the wall itself) during the construction period. The high cost and construction difficulty of a very low permeability wall mitigated against such an approach. A separate hydraulic wall was therefore proposed to effectively recharge the soil on the outside of a conventional cut-off wall. This hydraulic wall comprised a curtain of wick drains surrounding the cut-off wall and charged with water. Control of seepage through an underlying aquifer by a cut-off wall was considered, but a more cost-effective method using recharge by wells was adopted when shown necessary. Monitoring of groundwater pressures around the site showed that the maximum change in water pressure was less than 1m head, the design criterion.

The Southbank Interchange of the Melbourne City Link Project is a permanent excavation over an area of 3ha and extends to a maximum depth of 9m, which is 6m below the ground water table. Design and construction approaches were developed to (i) control seepage into the excavation to limit groundwater lowering beyond the site, and (ii) limit the effects of potentially damaging base heave during construction (Ervin et al, 2004). Lateral flow of groundwater into the excavation was controlled by a cut-off wall extending through the Coode Island Silt with a surrounding line of closely spaced recharge wells. In addition deep recharge of an underlying aquifer was used to control vertical seepage. Shallow pressure relief drains were installed to limit uplift pressures and control base instability in the deepest parts of the excavation.

6 ACKNOWLEDGEMENTS

The writer was initially involved with the Theatres Building while on the staff of the University of Melbourne where he was helped and encouraged by Professor Len Stevens. From 1975 with Golder Associates Pty Ltd, Dr Len Walker in particular gave great support.

Soilmech Pty Ltd provided a lot of the instrumentation and testing particularly in the early years of the project under the able direction of Ken Chandler. Finally, John Connell and Associates Pty Ltd provided great leadership and the writer particularly thanks Andrew Goad for his advice and assistance over the years of the project. The plates and figures are courtesy of John Connell and Associates.

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VICTORIA CHAPTER

By the time the AGS Victoria Chapter was established in 1970, there had already been impressive feats of geotechnical engineering in Victoria. These early works included: Princes Bridge (1888), an early example of staged construction on weak foundations; rerouting and widening of the Yarra River (1880) under direction from John Coode, who gave his name to Melbourne's problematic soil Coode Island Silt; Latrobe Valley Coal Mine, Yallourn Power Station and Kiewa hydroelectric scheme; the comprehensive Melbourne Metropolitan Board of Works sewage schemes; and tireless geological mapping and notable work of Alfred Selwyn who mapped swathes of Victoria to renowned high standard.

1 AUSTRALIA FELIX

Present day Victoria is humming with construction projects including major road and rail infrastructure, off-shore wind farms and rapid urbanisation in the largest urban renewal project Australia has ever seen i.e. Fishermans Bend Project. Professionals including Geotechnical Engineers and Engineering Geologists are moving to Victoria to take advantage of employment opportunities. Victoria's growth rate varies between 1.0 % and 2.5% and has a projected population of close to 10 million by 2060. Whilst a lot of the growth is Melbourne centric, there is similar growth occurring at the other major Victorian hubs: Geelong, Ballart and Bendigo.

With so much construction activity, there has never been greater need for continued geotechnical learnings and to distribute those learnings. That is the continued remit of the AGS. Through evening lectures, symposia, theoretical and practical courses, field excursions and workshops, the AGS hopes to facilitate the cross sharing of information between engineers, geologists, geophysicists, geodigital enthusiasts and academics. As the AGS commemorates 50 years, this article attempts to capture some of the geotechnical history of our own Garden State.

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As Clear as Mud

A lawyer's view of Geotechnical Engineering:

     one borehole       -    certainty
     two boreholes      -    doubt
     three boreholes    -    confusion
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2 ROCK SOC

Understanding geology and geomorphological processes is the cornerstone of geomechanics. It is a science, an art and a mystery. It is a body of work that is not complete and can be subject to debate sometimes heated. It is continuously added to, improved, worked on, renamed and redated.

The 2019 AGS Victoria symposium was on "Geotechnical Characterisation – managing design and construction risk". The overwhelming response in the form of abstracts and submissions demonstrates how much interest and continued learning there is in the field. And with good reason. The geology of Victoria is vast, complex and spans some 540 million years from the Early Cambrian greenstone belts at Heathcote and Mt Wellington, to the present day sedimentation within the Yarra River.

The government, in some form or another, has been mapping the geology and drilling holes in Victoria for almost 170 years. The economic, social and political needs of the state have changed considerably throughout this time, from goldfields to coal, from hand drawn sketches to digital databases.

The first record of geology in Victoria was in 1797 with George Bass noting granite at Wilsons Promontory. The names of many of the early geological contributors are immortalised as place names such as Charles Sturt, Pawel Strzelecki, Edmund Charles Hobson and William Westgarth.

The systematic account of Victorian geology was undertaken by Alfred Selwyn and published in the "Handbook of Australasia" in 1859. The Quarter Sheets were issued in 1863, followed by many other reports and maps. Contributors to geological and geomorphological understanding over the past 50 years include Fons Vandenberg, John Neilson, Neville Rosengren, Peter Dahlhaus, Eric Bird, Rob Wilson, Darren Paul and Tony Miner, amongst others.

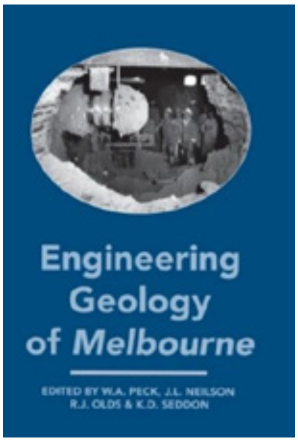
The contribution of AGS Victoria and its members to this field is still strong and is reflected in our annual geology seminars, field trips, and publications in Australian Geomechanics Journal such as "The Newer Volcanics 'hyaloclastite', Melbourne: geology, geotechnical properties, and engineering implications" by Schofield, or "Engineering geological evolution of the Jolimont Valley, Melbourne, Victoria" by Paul and his co-authors.

John Neilson (left), and Fons Vandenberg (right), respective winners of the Selwyn medal for outstanding contribution to geology in Victoria

3 THE BLUE BOOK

"In 1989 the Victorian chapter of the Australian Geomechanics Society decided to compile a book entitled 'Engineering Geology of Melbourne', following the Sydney version published in 1985. A committee of four was established, being Warren Peck, John Neilson, Keith Seddon and Roger Olds; a mixture of geologists and engineers with academic, government and private sector experience. We established the concept to have chapters covering both the geology and engineering aspects of each major geological unit of Melbourne and its suburbs, with each chapter written by someone with relevant knowledge or the ability to compile the data. But we knew that no individual would know it all so we asked the geotechnical community to share its information for the good of the industry. This valuable IP was shared in the way of borehole logs, laboratory and field test data and engineering practices so that the knowledge base could be maximised. We also thought it valuable to have chapters on engineering hazards, construction materials and special engineering issues, so that it could be a book practitioners could use for easy reference.

The initial target to publish within one year proved optimistic, as organising nearly 50 separate authors to take on the task and then deliver to a timetable proved challenging. It was three years of our lives that the editorial committee will remember well, despite it now being 30 years since we started this labour of love. I believe the end result exceeded our expectations in terms of the benefits it has provided to the industry over the past 27 years since publication. I know I still refer to it on a regular basis and it is pleasing to see copies of it floating around the offices I have worked in.



It would be great if the AGS could form a team to update the book to create volume 2. We know the geology hasn't changed but we have so much more data available now on which to update the stratigraphy and engineering experience. It would be incredibly valuable if the next generation would pick up this challenge." Roger Olds, 2019

4 RAIL

It certainly is an exciting time in Victoria for geotechnical professionals interested in rail with several major rail infrastructure projects underway or in planning.

Victoria's first railway line was opened three years after the gold rush of 1851. The rail line connected the Melbourne Terminus (i.e. Flinders Street Station) to Sandridge (i.e. Port Melbourne). The railway line was built by privateers including the through-girder rail bridge over the Yarra River, currently used as a pedestrian bridge. The Argus newspaper described it at the time as 'memorable in the annals of Victoria and Australia' as the railway line was Australia's first.

The first rail state authority was established in 1856 although private enterprise largely continued to fund rail projects. The gold rush and prosperity in Victoria led to speculation in land and buildings. Bust inevitably follows boom. After the "Black Wednesday" crash in 1878 many private rail companies defaulted and the state rail authorities stepped in to take over their operations.

The framework of the present-day rail infrastructure was established in the Victorian era including Sandringham, Williamstown, Essendon, Epping, Frankston and Belgrave Lines and regional services such as Melbourne to Geelong, Albury Wodonga and Gippsland. Interestingly the Doncaster Rail line was initially proposed in 1890. Although construction for the line commenced in 1974, backlash due to escalating costs saw the project cancelled just two years later and cuttings were backfilled. The project resurfaces sporadically particularly as counter points to road projects such as East West Link and North East Link.

Plans for MURL or City Loop were initially presented in the 1969 Melbourne Transportation Plan. Construction commenced in 1971 and it took 14 years to complete the 4 rail tunnels and associated stations. This project was one of the first to use detailed tunnel face mapping. Several papers were published on the tunnel and reported in the proceedings of the Fourth Australian Tunnelling Conference held in Melbourne in March 1981. A summary of construction of the loop also appears in the chapter on Tunnels in "Engineering Geology of Melbourne", 1992 (i.e. The Blue book).

Investigations for a second underground rail beneath Swanston Street servicing the CBD started around 2004 but were delayed a number of years when an alternative route to the west of the City was investigated. In 2017 early works construction for the Metro Tunnel Project commenced with construction of the stations and tunnels, now well under way, scheduled for completion in 2025. The project takes the Sunbury and Dandenong lines out of the City Loop through new dedicated tunnels running up St Kilda Road and Swanston Street through the CBD and includes four new stations.

Design has had to consider construction of Melbourne's largest underground caverns for the CBD stations as well as tunnelling through complex variable ground conditions containing multiple aquifers. A joint event between AGS Victoria and the International Association of Hydrogeologists Australia entitled an "Improved understanding of Melbourne's hydrogeology gained from investigations and numerical modelling of large civil infrastructure projects" gave some insight into some of these hydrogeological considerations. Rob Day (recipient of the 2016 AGS Practitioner Award), discussed some groundwater control considerations in an AGS presentation in 2017.

From 2009 to 2015 the 48km long Regional Rail Link was built. It was one of the first new rail lines in Melbourne for decades. The rail link separated regional services heading to Ballarat, Bendigo and Geelong from the electrified suburban rail network between Southern Cross station and Werribee. The project had to tackle expansive soils and deep cuttings in hard basalt rock both in greenfield sites and densely urbanised areas including adjacent rail tracks. Another aspect of the project included the ground improvement works through the deep, soft Coode Island Silt between City and Sunshine. Instrumented trial embankments were constructed as part of the project, the results and conclusions of which have been published in the AGS Journal, amongst others publications.

Melbourne is a relatively flat city, resulting in over 130 level crossings between road and rail in the original suburban rail network which has led to traffic congestion and safety issues. The government decided to tackle these hazards and improve some of the existing rail stock and in 2006, the first of the rail grade separation projects was undertaken at Middleborough Road on the Ringwood line.

The Level Crossing Removal Authority is currently managing a program consisting of over 70 level crossing removals. A recent paper in the AGS journal entitled "Recent experiences with soil nailing in deep cuts as part of level crossing removal works in Melbourne" by Gniel, Lenthall and Paul, highlights some geotechnical considerations on these projects. Future rail projects include the suburban rail loop proposed 90km-long orbital railway network.

5 ROADS

The gold rush in Victoria was one of the reasons why population centres spread throughout Victoria. A dense network of roads was established to connect the centres. In 1982 there were 2 million vehicles registered in Victoria. Today there are over 5 million.

Victoria was key in the development of road management in Australia. The first ever state road authority in Australia was established in Victoria in 1913. Early predecessors of VicRoads included the Clerk of Works, the Central Road Board, Board of Land and Works, Country Roads Board and the Road Construction Authority. Two wars impeded the progress of developing national guidelines and systems, and it wasn't until the 60s /early 70s, that the Australian Government established delivery mechanisms for the construction and maintenance of roads, setting design standards and establishing priorities. The Australian Road Research Board (ARRB) was created in 1960, with its headquarters in Victoria, to coordinate and encourage research into all aspects of road-making, planning and management.

"Any discussion on the history of roads in Victoria, Australia or globally that does not reference the many books written by Dr Max Lay, Chief Executive of ARRB and Director of Major Projects of VicRoads, will be deficient." David Mangan, 2019.

The 1969 Melbourne Transportation Plan was a road and rail transport plan for Melbourne, created by Henry Bolte's state government. The plan was largely focused on freeway projects, many of which have been completed.

The Lower Yarra Freeway or West Gate Freeway opened in 1971, followed by West Gate Bridge in 1978. There were multiple geotechnical challenges throughout the project, not least its complicated geology and deep soft soils (in excess of 30m). It was also one of the first projects to construct large earthfill embankments from highly expansive basaltic soils based on suction theory. A paper on the pile design for the project is presented in an AGS Journal entitled "Predicted and measured behaviour of laterally loaded piles for the Westgate Freeway, Melbourne" by Hughes et al. Since construction, the freeway has been continuously upgraded and extended with new interchanges. Of interest is the Southbank Interchange, on which a paper was issued in the AGS Journal and entitled "Melbourne's Southbank Interchange: a permanent excavation in compressible clay" by Max Ervin (recipient of the 2006 AGS Practitioner Award) et al. The West Gate Tunnel Project is currently under construction to provide a second river crossing along the busy thoroughfare. The $7B tunnel and viaduct has an opening date of 2022. AGS Victoria looks forward to the papers and presentations that will follow in its completion.

The Eastern Freeway was constructed in 1977. It was a controversial project that was partly blockaded and had cost blow outs. Part of the cost blow out was attributed to the limited geotechnical investigation conducted prior to commencing construction which was discussed by Dr. Richard Evans of CRB. at an AGS Victoria event in 1981. The political turmoil that the freeway created, terminated new freeway projects until the mid-1990s.

Freeway construction resumed in the 1990s, with the construction of the Western Ring Road, CityLink (two tunnels under the Yarra River) and others.

Most of these freeways are expected eventually to join in a continuous and extensive network. The North East Link and Suburban Roads projects are currently at tender stage, which will contribute to this continuous link.

The Melbourne Times cover: 'The Freeways Are Coming!' (29 October 1975)

Source: http://www.ycat.org.au/1977-the-battle-of-alexandra-parade/3/

Highway construction in Victoria is often used as case studies for AGS papers, symposia and evening lectures. Some iconic papers include the paper by Peter Balfe and Jim Holden of CRB on dynamic testing of piles in 1983; and Tom Flintoff (former AGS Victoria Chair) on geology and road construction.

The basement geology of Melbourne is the Silurian age Melbourne Formation of weathered siltstone with minor sandstone beds. As such, soft rock engineering is commonly a requirement in highway construction. Monash University was particularly active in this area with major research themes and modelling software. Ian Johnston (former AGS Victoria Chair) won the E H Davis Memorial Lecture in 1991 for the work conducted on "Geomechanics and the emergence of soft rock technology".

"I was involved in some interesting geotech aspects of Melbourne infrastructure. In the 1980s especially, I was with VicRoads doing some major bridge geotech investigations, and deep piling design and construction through South Melbourne on the Westgate Freeway. That project saw a range of innovations, which put VicRoads into the national and international limelight at the time for cutting edge geotechnical engineering. Obviously it was a team effort, but much was achieved."
Warren Pump, 2019

6 "JEFFED"

Victoria has experienced its fair share of boom and bust economies. Perhaps the bust in the 90s had more influence on the geotechnical community than others. At the time, Victoria's finances were in billions of dollars of debt (>$30B) and the Victorian government brought in privatization and sale of state assets to stem financial losses and boost Victoria's economy. The privatization led to the loss of more than 100 state run services such as power, ambulance and prisons. Some 50,000 public servants lost their jobs. Another casualty was the demise of some of the state funded geotechnical research in Victoria: CSIRO geomechanics division, the State Electricity Commission of Victoria (SECV) and the Engineering Geology Section of the Department of Mines.

7 PORTS

Station Pier in Port Melbourne was Victoria's welcoming point for migrants until aeroplanes replaced ships in the early 1970s. With the demise of ships for passenger travel, The Harbor Trust Chairman, Victor Swanson, developed plans for a container dock in Melbourne. Swanson Dock West was opened in 1969. The associated container terminals were largely built on the estuarine flats and reclaimed land of the Yarra River which resulted in a reasonable amount of geotechnical engineering due to deep deposits of Coode Island Silt. The AGS Victoria seminar in 1990 looked back over case histories of the development of these heavily loaded pavements on soft soils.

Victorian editorial panel of *Australian Geomechanics* 1993-94

Station Pier in Port Melbourne
Source: https://www.vicports.vic.gov.au/about-us/port-history/Pages/station-pier-history.aspx

To facilitate shipping, channel deepening works have been undertaken within Port Phillip Bay. In 1883 and 1916 the "Rip" at Port Phillip Heads was deepened using explosives. In 2008, a channel deepening exercise was undertaken as part of a $1B PPP scheme. The project involved dredging/deepening the channel by about 2m and placing the dredged materials in storage dams that were constructed on the sea floor. A paper discussing the works was presented in an AGS Journal at that time entitled "The design and performance of a submarine bund in Port Phillip, Victoria" by Ramsey et al. The material to be excavated as Moorabool Viaduct Sandstone was assessed for rippability by Delph University in a quarry in Portland using instrumented blades/cutting tools. The AGS hosted seminars and workshops around Australia shortly after the project was completed.

8 CSIRO

The headquarters of the CSIRO Division of Geomechanics was based in Syndal, Melbourne, between 1983 and 1993 with Dr Gordon Douglas Aitchison at its head. CSIRO conducted research projects in conjunction with academics and other state authorities. Notable studies conducted by or through CSIRO include: assessment of the seasonal changes in water content resulting in swelling and shrinking soils, methods of assessing dispersive soils, devising methods and laboratory models to study interactions between building loads and the settlement, as well as the development and verification of computer programs for modelling such as CIRCLY. Walsh, Holland and Kouzmin (current editor of AGS Journal) of CSIRO wrote a paper titled "The Classification of The Expansive Behaviour of Melbourne Soils for Domestic Construction" in 1976.

At Syndal there was a comprehensive geotechnical laboratory and its engineers and scientists were recognised internationally as leaders in their fields. The CSIRO regularly presented at AGS Victoria events.

The geomechanics division was closed in 1993 and the focus shifted entirely to exploration and mining. The extensive geotechnical laboratory equipment at Syndal was sold, and what was estimated at about $2M was sold for a sum of about $300k.

9 SECV

The State Electricity Commission of Victoria was created in 1918 to govern capital works related to power generation, distribution and everything in between. The SECV maintained a large geotechnical group as the complexities of delivering these capital works included mining, stability, settlement, subsidence, foundations, earthworks and retention.

Don Raisbeck, formerly head of SECV geotechnics team and a past chair of AGS Victoria, indicated that the SECV served as a training ground for junior geotechnical professionals and provided experienced professional to private enterprise. Past employees of SECV include esteemed local geotechnical practitioners such as Ian Pedler.

In the 90s, the SECV let go of 850 engineers including all the geotechnical staff. A core group in Latrobe Valley remained, attributed to the union in that region and the complexity of the work. Geo-eng Australia formed out of SECV, was eventually taken over by GHD.

10 DEPARTMENT OF MINES

The Mines Department (also known as the Department of Mines and the Mining Department) was formed in 1909. In the geotechnical space, their work is best known for their contribution to understanding Victorian geology and quality boreholes (some 70,000 boreholes) that are still sourced and referenced in many infrastructure projects today. In the 1970s the Mines Department had their own fleet of drilling rigs. By the 1980s, the drillers were largely privately sourced. One of the Mines Department drillers Sandy (Alexander) James formed AS James.

The group was also responsible for the creation of a geotechnical data bank in 1984 to collate and provide centralised access to existing State data. Today this database can be accessed through the geo.vic website.

John Neilson as head of the Engineering Mines Department devised the weathering classification standards for Melbourne's sedimentary bedrock, details of which can be found in the "Blue Book".

11 BROWN GOLD

The 2019 AGS Victoria fieldtrip went to Latrobe Valley, located in eastern Victoria. A repeat of the initial AGS field trip undertaken in 1981 conducted in tandem with the SECV.

stations located at the edge of the mines. Ten years ago the annual combined coal production from the Loy Yang, Yallourn and Hazelwood mines was around 60 Mtpa.

There have been lots of challenges in setting up and operating these very large open cut mines. Not least has been to ensure mine stability requiring extensive geotechnical oversight. The mines are deep (up to 220m deep) and cover large areas. With relatively thin overburden cover and thick coal seams, the mine batters are mainly composed of coal providing both a fire risk and a number of geotechnical challenges. During mining, major earth movement risks were:

- **Stress relief movements:** These occur in the mine batters and around the edge of the mine during the initial excavation and deepening of the mine. The movements are slow but sufficiently large to cause strain cracking and to require infrastructure design consideration.
- **Controlling high water pressure in aquifers beneath the mine:** Pressures can be sufficiently large to cause heave and flooding in the floor of the mines. Pumping management is required to ensure safe levels are maintained across the mine floor.

AGS Victoria field trip 2019 to Latrobe Valley

For more than 90 years, electricity in Victoria has been generated from brown coal supplied from large, deep open cut mines in the Latrobe Valley. The Latrobe Valley formed some 100 million years ago in a land lush with vegetation. The gradual deposition of this vegetation created a sedimentary basin about 700 metres thick. The lignite in Latrobe Valley has seams up to 150m thick and ranges from 50 (Traralgon seams) to 5 (Yallourn seams) million years old. The brown coal deposits of the Latrobe Valley are the largest of their type in the world. As Herman (1922) stated "brown coal in Victoria is like a huge fortune in chancery".

Open cut mining has been achieved by the use of large scale mining equipment, conveyors and large raw coal bunkers providing a "just-in-time" delivery system to power

Due to pumping in the mines and by other water users, large scale regional subsidence is occurring with subsidence of up to 2.73m recorded by 2015 adjacent to Hazelwood Mine. The settlement rates are typically less than 10 mm/year with very low differential settlement away from the mines. Paul Schneider of the SECV gave an AGS evening lecture on the use of magnetic settlement gauges in 1983.

- **Reduce the risk of large scale coal block movement in mine batters:** The mine batters are mainly composed of coal. The coal is 'cut' into large blocks by pre-mining near vertical joints; is light; and readily reacts to high water pressure sometimes found within the mine batters. Beneath the coal seams there is low shear strength interseam material. Under certain conditions, particularly if coal joints fill with water, these blocks can move towards the mine. This can occur if coal joints fill from surface water ingress after rainfall, or fire service spraying. Horizontal drainholes are used to help control the water levels in joints.

A paper was presented in an AGS Journal in 1994 entitled "Geocomposites for batter stabilisation Yallourn Open Cut Brown Coal Mine" by Jennings and Kacavenda.

The environmental landscape of the world is changing. In 2017 the Hazelwood Power Station and mine were closed and are now in a rehabilitation phase. The geotechnical challenge for rehabilitation works is to make the remnant voids safe and stable for a sustainable solution. With insufficient overburden to fill the mines, there is a long-term challenge posed to mine floor stability by rising aquifer pressures, and to batter stability from changing coal water levels.

At Hazelwood a lake has been incorporated into mine rehabilitation plans to provide a safe and stable solution.

The AGS Victoria hosted a presentation in 2019 on the "Latrobe Valley Mine Closure: An Emerging Case Study" which was followed the week after with a field visit of the mine.

Victoria is now looking to wind and solar as alternative, sustainable electricity sources. Victoria's current capacity is almost 2500 MW from existing wind and solar farms, with double that in planning or construction phase. The construction of these farms requires geotechnical input due to large, oscillating loads, expansive soils as well as construction of access roads and services in remote areas of Victoria. The 2020 AGS Victoria Symposium is on sustainable geotechnics, and we are looking forward to hearing more on these challenges.

12 WATER WORKS

Victoria has about 450,000 dams, with the majority of the larger dams being the responsibility of State government authorities. The State River and Water Supply Commission (SRWSC) was established in 1905 with a principal aim of irrigation for agriculture. Melbourne and Metropolitan Board of Works (MMBW) and numerous regional water boards managed and built dams, and set aside catchments for with potable water supply.

The period through the 1970s - 1980s saw the last phase of major post-war dam construction in Victoria, including the completion of dams such as Cardinia (1973) and Sugarloaf (1981). SRWSC completed Dartmouth Dam in 1979. At 180m high and an embankment volume of $14Mm^3$, it is considered to be the largest volume / height, rockfill dam in the southern hemisphere.

Latrobe Valley mine 1920s Source: Latrobe Valley Geotechnical Group (courtesy of Rob Gaulton and Ben Jansen)

The Latrobe Valley Geotechnical Group (LVGG) was formed in 2013 by the Geotechnical and Hydrogeological Engineering Research Group (GHERG) funded by the Victorian Government through the Department of Economic Development, Jobs, Transport and Resources. Their inaugural meeting was held on the 8th November 2013 chaired by Rae Mackay. The team was part of the Monash University Churchill Campus which later became part of the Federation University.

Soon after, the Melbourne Metropolitan Board of Works completed Thompson dam, at 166m height and with a very similar embankment volume. Jeremy Barber (former AGS Victoria Chair) published a paper in an AGS Journal in 2011 on "Sugarloaf pipeline landslide risk management and planning approvals" discussing some interesting elements of this project.

Some of the earlier larger dams were systematically upgraded in this period to align with the new rainfall and runoff guidelines which included the re-estimation of design flood and spillway capacity. This resulted in significant scope for geotechnical engineering input into dam wall investigation and design.

The SRWSC were active in geotechnical research such as new compaction control measures for high plasticity clay, and were common contributors to AGS Victoria events. John Holland of SRWSC conducted studies on expansive clay soils, which became a major focus of research for design of lightly loaded footings. A E Kelso of Melbourne Metropolitan Board of Works developed the earliest formulation of Moisture-Density relationship, still in use today.

The Victorian State Government amalgamated the local water boards into a smaller number of larger regional authorities in the 90s. Melbourne Water was established to manage the ten Melbourne reservoirs.

Throughout the rest of Victoria the water authorities became Goulburn-Murray Water, Southern Rural Water, Lower Murray Water and Grampians Wimmera Mallee Water. This resulted in a period of activity as the newly formed authorities worked to understand the condition and safety of all their new portfolios (which included some very old dams, some in disrepair).

There were some interesting dam incidents and failures over the period, often related to dispersive erosion and piping. These included a large off stream irrigation dam near the Murray River (erosive piping through foundations), dispersive piping of embankments associated with a water treatment facility near Melbourne, and the failure of the Morwell River diversion over the Yallourn coal mine due to piping, as well as many smaller failures often associated with farm dams.

In the present century, with most of the better dam sites already utilised, water supply works for Melbourne turned to desalination. The desalination plant was originally suggested after the droughts that occurred in 2000. The project went under construction in 2009 at Wonthaggi, south east of Melbourne, and was completed in 2012. Considerable geotechnical engineering was required to construct the underground tunnels located 15 metres below the seabed measuring 1.2km and 1.5km long and each with a 4 metre internal diameter, as well as the 84km transfer pipeline.

Research and innovation in the geotechnical and water aspects of dams have also been the focus of many Victorian universities in recent years to address the challenges encountered by the industry. Some of the geotechnical related research projects currently in progress encompass improvements in design and construction of embankment dams including study of static and seismic liquefaction, deformation analysis, and mechanical behaviour of rockfill materials. For example, the latter research at the University of Melbourne is intended to improve the understanding of the mechanical behaviour of rockfill, the main construction material for many rockfill dams (e.g. Dartmouth). A discrete element numerical method (DEM) is employed to simulate large scale laboratory testing in order to study the stress-strain response and strength characteristics of rockfill. The effects of different parameters which are known to influence the strength and deformation characteristics of rockfill, such as relative density, gradation, particle strength and shape, are being investigated resulting in a better understanding of the long-term behaviour of rockfill dams.

The 2020 AGS Victoria field trip was intended to comprise a joint visit with ANCOLD to the Upper Yarra Dam to observe the recent upgrade works. The AGS will work to reschedule this trip to 2021.

13 OUTWARDS, UPWARDS AND DOWNWARDS

Victoria is growing. To accommodate the increasing population, urban centres are rapidly moving outwards with new residential subdivisions and town centres. Within cities, buildings are also getting taller and basements are going deeper. Melbourne is now home to more than 50 sky scrapers.

One of the challenges of suburban development in Victoria is the presence of reactive clay soils, which covers vast areas of land from inner west Melbourne to Horsham in the north-west of the state. This geotechnical challenge has been the focus of many studies by local academics, industry and with seminars hosted by the AGS Victoria. RMIT University has contributed heavily to this area through delivery of technical notes, AGS Victoria Symposium talks (Jie Li) and publications in the AGS journal on characteristics of reactive basaltic clays of Victoria and the impact of trees and climate change on damage to residential footings. Swinburne University of Technology has also contributed to this area mainly by monitoring ground movement and also modelling interaction of slabs with reactive clays which was presented as a keynote by Emad Gad at the AGS Victoria 2016 Symposium and has been shared with the wider professional community with more than 20 Victorian papers issued through the AGS Journal on this topic.

In 1987, AGS Victoria hosted a seminar to discuss the impact of the new (at that time) AS2870. Panelists included Peter Yttrup, Don Cameron, Paul Walsh, Ken Morris and Russell Brown. The 1980s version of the Australian Standard AS2870 had strong input from John Holland of Swinburne University amongst others.

With the outbreak of the millennial drought in 2007, the number of court cases and incidents resulting from damage of reactive clays to light structures has increased significantly.

Consequently, after a period of less attention (compared to earlier research carried out at Swinburne University and others), the Victorian universities and AGS Victoria started to pay more attention to this widespread problematic soil.

In 2016, the AGS Victoria held a symposium on the "reactive soils and footings" to provide an update on the current understanding of the standard and on construction practices.

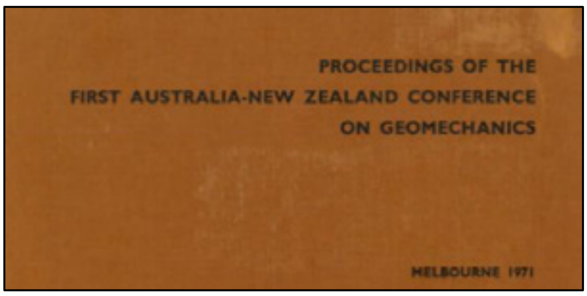
Chris Haberfield (former AGS National chair and AGS Victoria Chair) presented results of numerical modelling on interaction of reactive clays with footings at the AGS Victoria 2016 Symposium as a keynote talk. In addition, work has been done at Monash University on damage caused by reactive clays to pipelines which resulted in Jayantha Kodikara of Monash University receiving the ARRB 2019 Research Impact Award. It is noted that the issues surrounding reactive soils and home owners are not yet resolved.

Private geotechnical consultancies and specialist geotechnical contractors started emerging in Victoria in the 70s and 80s. It was in this era that buildings started going higher and deeper with a need for understanding foundation piles and retention piles. The design and construction of piles in Melbourne featured in AGS publications and seminars. Notable papers include "Footing for Eureka Tower" and "Groundwater control for Art Centre". The Crown Towers is proposed for construction and it will be Melbourne's tallest building – a $1.75bn, 90-storey hotel and apartment development.

Soilmech P/L (Douglas Partners) was one of the first privately owned geotechnical firms in Melbourne with Ken Chandler as director. Other companies included MPA Williams and Associates (ATC Williams), Coffey Partners, GHD, Golder Associates, Piper and Associates (Cardno), Maunsell (Aecom), and Geotech Group (Acciona).

14 AGS VICTORIA CHAPTER

The AGS Victoria Chapter was established in 1970 and the first meeting was chaired by Dr Charles Gerrard. A time line of notable events is provided at the end of this paper. The very first ANZ conference was held in Melbourne in August 1971. The 11th ANZ conference returned to Melbourne.

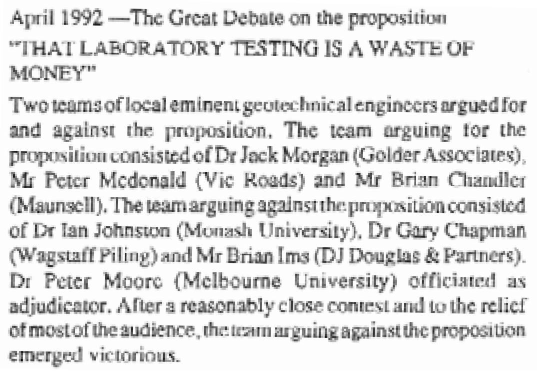


The best paper award for the conference was given to the Geotechnical Engineering Team at the University of Melbourne for their work on shallow geothermal energy and energy geo-structures led by Ian Johnston and Guillermo Narsilio (both former AGS Victoria chairs).

The AGS Victoria Chapter is an active group largely due to the interest of local members. In fact, it was the AGS Victoria Chapter, notably Ian Johnston, who created the Australian Geomechanics News after the demise of the AGS Journal in 1979.

The logging course has been run almost yearly since 1979, with Mark Kurzeme, M Asten and David Joran providing their insights on logging at Clunies Ross House. The AGS Victoria Chapter held the 2019 logging course at the excellent facilities of Swinburne University of Technology. The AGS run their own events as well as aiding other societies when required; for example the 5th International Congress on Rock Mechanics in Melbourne was organised by Bill Bamford (former AGS National Chair) in 1983, and the many joint events with the Australian Tunnelling Society.

The AGS Great Debate on soil testing was originally hosted in Victoria in 1992. The great debate was repeated in Sydney in 2000. Both times the motion was defeated. The full details of the Sydney debate can be found in the AGS Journal September 2000.


April 1992 —The Great Debate on the proposition "THAT LABORATORY TESTING IS A WASTE OF MONEY"

Two teams of local eminent geotechnical engineers argued for and against the proposition. The team arguing for the proposition consisted of Dr Jack Morgan (Golder Associates), Mr Peter Mcdonald (Vic Roads) and Mr Brian Chandler (Maunsell). The team arguing against the proposition consisted of Dr Ian Johnston (Monash University), Dr Gary Chapman (Wagstaff Piling) and Mr Brian Ims (DJ Douglas & Partners). Dr Peter Moore (Melbourne University) officiated as adjudicator. After a reasonably close contest and to the relief of most of the audience, the team arguing against the proposition emerged victorious.

There have been three special editions of the AGS Journal dedicated to geotechnics in Victoria: Geotechnical Practice in the Victorian Region (2006), Victorian Geotechnics (2010) and Geotechnics of Victoria (2014) where interestingly a shift of focus from piling works is noticed to work on problematic soils and in particular Coode Island Silt and basaltic expansive clays based on the number of publications in each area.

"I have been going to AGS meetings since doing my Masters in about 1977. It was an exciting time back then to be involved in geomechanics as it was a new and emerging industry. At that time, there was a strong presence of geotechnical engineering within many Government Authorities, resulting in a recognition of its importance. AGS Conferences were a great source of knowledge.

The geomechanics consulting business has changed greatly over that time, and mostly improved. Initially geotechnical investigations involved drillers going to site, conducting the drilling and logging the ground. The poor logs gradually resulted in full time supervision by geologists and geotechnical engineers that mostly continues today.

Health and Safety has changed the way investigations and site inspections were carried out. As a young graduate it involved the inspection of the rock sockets by entering the excavated pile hole by putting your feet in the excavation bucket and being lowered some 40m into an uncased pile excavation, a quite dangerous and unsafe experience which thankfully has been discontinued. Health and Safety has also greatly improved during geotechnical investigations.

While in the early days and pre–computers, geotechnical analyses involved extensive hand calculations that in many ways are still preferable although the use of computer programmes, particularly Finite Element Modelling (FEM) programs, have greatly changed the geotechnical designs. The first computer programmes involved slope stability analyses with card punching and over-night runs. It was quite a slow process. With the advent of personal computers this changed rapidly, leading to the heavy reliance on computer modelling today. The FEM in some ways results in a lesser understanding of the designs, although in complex situations they certainly better model the soil interaction effects." John Piper, 2019

15 BAMFORDS

As a token of appreciation at AGS Victoria Chapter events, speakers are presented with a "Bamford". A Bamford is an oblique-sliced core of Harcourt granite (from Victoria) with a medal affixed. They are thus named Bamford after Bill Bamford who graciously supplies AGS Victoria with the rock core.

Bill originally came up with the idea of an oblique cut core as tribute for another reason, this is what Bill had to say:

"The idea for what others have termed the 'Bamfords' goes back to an homage to Professor John Jaeger, one of the greatest pioneers of rock mechanics."

As the immediate past-chairman of the Australian Geomechanics Society (and his successor as Vice-President of the ISRM) I was then given the task of devising a suitable memorial tribute to him. I was influenced by his pioneering high-pressure triaxial testing of rocks (in association with Mervyn Patterson, Kevin Rosengren, Earl Hoskins, and Ted Brown)." Bill Bamford, 2016

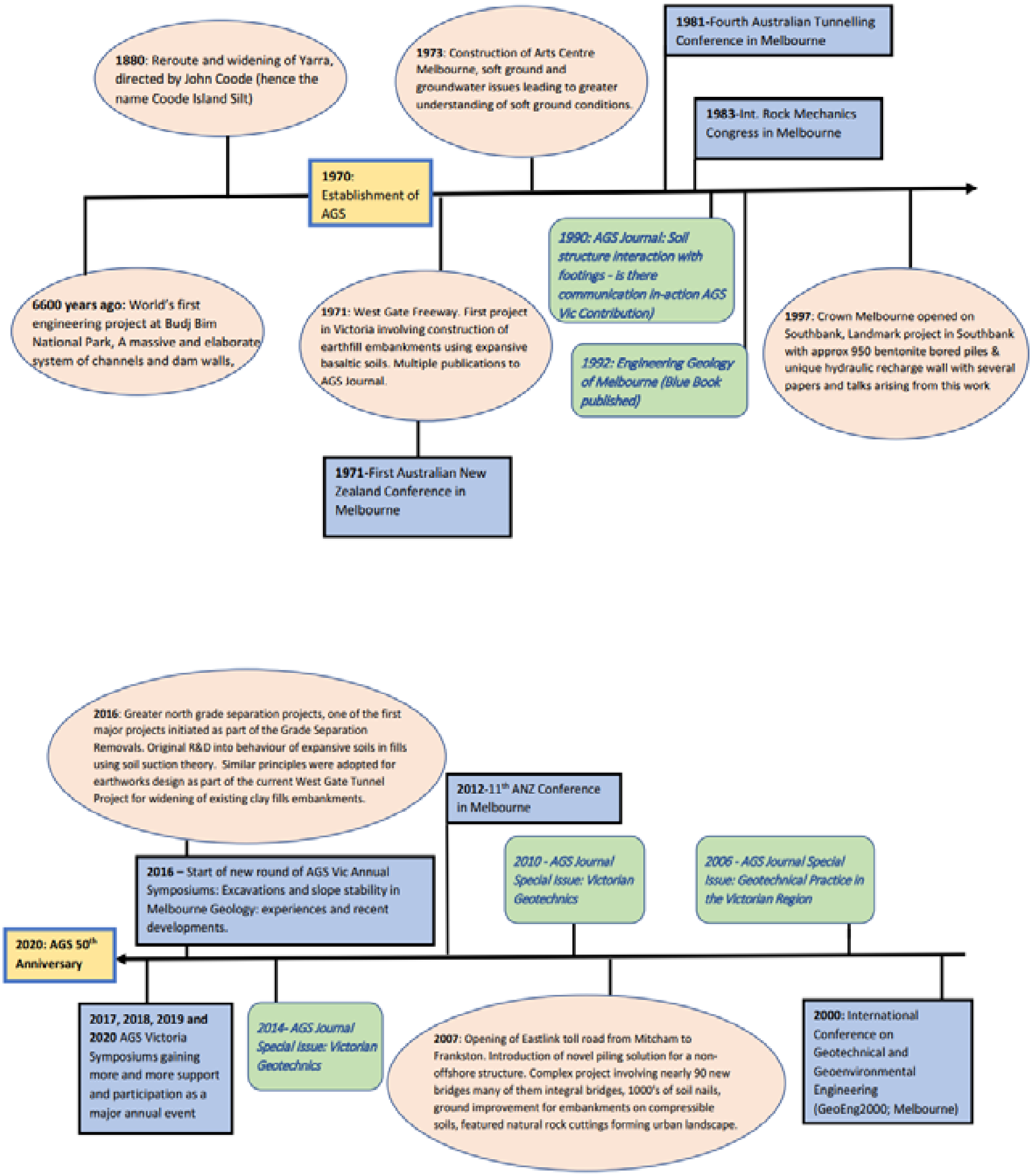
16 THE JACK MORGAN YOUNG GEOTECHNICAL PRACTITIONERS AWARD

The Jack Morgan Young Geotechnical Practitioners Award is an AGS Victoria award presented every two years to an outstanding Victorian geotechnical practitioner under the age of 35. The award was established in 2009 and the inaugural recipient was Guillermo Narsilo (former AGS Victoria chair). Narsilio was the first and only Australian to receive the ISSMGE Young Geotechnical Award, presented to him at the ISSMGE Conference, France, 2013. The award is in honour of Jack Morgan, a stalwart of geotechnical engineering in Victoria. Jack has been an academic (with the University of Melbourne), worked for government as well as Managing Director of Golder Associates. Jack pioneered work on deep basements in Melbourne and wrote the paper on basement construction in the Engineering Geology of Melbourne "Blue Book". The Arts Centre basement is one of the earliest large soft ground basements in Melbourne, one on which Jack had a significant involvement.

17 ACKNOWLEDGMENTS

Many thanks to all the contributors and editors of the Victoria Chapter History article including Don Riasbeck, Rob Day, Lucie Missen, Behrooz Ghahreman-Nejad, Keith Seddon, Slavko Kacavenda, Ben Jansen, Roger Olds, John Piper, Warren Pump, Tanya Kouzmin, Bill Bamford, David Mangan, Michael Broise, Dave Tully, Andrew Murphy, Trevor Smith, Daniel King, Chris Coulson, Mahdi Disfani and Clare Bridgeman.

Inevitably, due to the limited available source material, the detail included in this history will have overlooked important events, awards and key personnel active in the Victorian geomechanics community. The authors sincerely apologise for any omissions and would welcome feedback such that the heritage of the AGS Victorian Chapter can be preserved.



Chronology of important construction events in Victoria, and of developments within AGS Victoria

VICTORIA CHAPTER

VICTORIA CHAPTER COMMITTEES

1970-1979 National Representatives: Mr Charles Gerrard, Mr F Taylor, Dr Marcis Kurzeme, Dr Len Walker, Mr Max Ervin, Mr John Styles

Year	Chair	Deputy Chair	Secretary	National Representative
1980	Dr Ian Johnston		Mr Warren Pump	Dr Ian Johnston / Mr Warren Pump
1981	Dr Ian Johnston		Mr Jeff Washusen	Dr Ian Johnston / Mr Warren Pump
1982	Mr Warren Pump	Mr Peter Hoadley	Mr Don Raisbeck	Mr Warren Pump / Mr Jeff Washusen
1983	Dr Bill Bamford		Mr Wayne Regan	Mr Don Raisbeck / Mr Wayne Regan
1984	Dr Bill Bamford	Mr Max Ervin	Mr Wayne Regan Dr Michael Dunbaven	Mr Max Ervin / Mr Paul Williams
1985-86	Mr Max Ervin	Mr Paul Williams	Mr Tom Flintoff	Mr Max Ervin / Mr Paul Williams
1987	Mr Paul Williams	Dr Marcis Kurzeme	Mr Tony Abs	Mr Max Ervin / Dr Ian Johnston
1988	Mr Tom Flintoff	Dr Gary Chapman	Mr Brett Thomas	Mr Tom Flintoff / Mr Brett Thomas
1989-90	Mr Tom Flintoff		Mr Robert Smith	Mr Tom Flintoff / Mr Brett Thomas
1991	Dr Marcis Kurzeme		Dr Chris Haberfield	Dr Marcis Kurzeme / Mr Robert Smith
1992	Dr Marcis Kurzeme		Dr Chris Haberfield	Dr Chris Haberfield / Mr Robert Smith
1993	Mr Ian Pedler	Dr Chris Haberfield	Mr Don Raisbeck	Dr Chris Haberfield / Mr Brian Chandler
1994	Dr Chris Haberfield		Mr Don Raisbeck	Dr Chris Haberfield / Mr Brian Chandler
1995	Dr Chris Haberfield	Mr Don Raisbeck	Dr Julian Seidel	Dr Chris Haberfield
1996-97	Dr Bill Bamford		Mr Andrew Campbell	Mr Brian Chandler
1998	Ms Heather Wardlaw		Mr Terry McKinley	Mr Stephen Newman
1999	Ms Heather Wardlaw	Mr Andrew Campbell	Mr Terry McKinley	Mr Stephen Newman/Dr Ian Johnston
2000-01	Mr Andrew Campbell		Mr Terry McKinley	Mr Allan Garrard
2002	Mr Andrew Campbell	Dr Bill Bamford	Mr Slavko Kacavenda	Mr Allan Garrard
2003	Dr Ben Collingwood			Mr Allan Garrard
2004	Dr Ben Collingwood			Mr Neil Benson
2005	Mr Neil Benson	Mr Michael Broise		Mr Neil Benson
2006	Mr Neil Benson	Mr Michael Broise	Mr Peter Reid	Mr Chris Boyd
2007	Mr Michael Broise	Mr Chris Boyd	Mr Peter Reid	Mr Chris Boyd
2008	Mr Michael Broise	Mr Chris Boyd	Mr Stephen Tyson	Mr Chris Boyd
2009	Mr Chris Boyd	Mr Slavko Kacavenda	Mr Chris Coulson	Mr Chris Boyd
2010	Mr Chris Boyd	Mr Slavko Kacavenda	Mr Chris Coulson	Mr Darren Paul
2011	Mr Darren Paul	Mr Chris Coulson	Mr Jeremy Barber	Mr Darren Paul
2012	Mr Nick Ramsay	Mr Chris Coulson	Mr Jeremy Barber	Mr Jeremy Barber
2013	Mr Nick Ramsay	Mr Jeremy Barber	Mr Chris Lyons	Mr Jeremy Barber
2014	Mr Jeremy Barber	Mr Chris Lyons	Dr Guillermo Narsilio	Mr Chris Coulson
2015	Mr Jeremy Barber	Mr Richard Kaser	Dr Guillermo Narsilio	Mr Chris Coulson
2016	Mr Richard Kaser	Dr Guillermo Narsilio	Dr Mahdi Disfani	Mr Chris Coulson
2017	Mr Richard Kaser	Dr Guillermo Narsilio	Dr Mahdi Disfani	Mr Chris Coulson
2018	Dr Guillermo Narsilio	Mr Chris Coulson	Ms Clare Bridgeman	Dr Mahdi Disfani
2019	Dr Guillermo Narsilio	Mr Chris Coulson	Ms Clare Bridgeman	Dr Mahdi Disfani

SOUTH AUSTRALIA AND NORTHERN TERRITORY

The AGS was established in 1970, as a non-profit organisation, to promote and advance the theory and practice of geomechanics and to provide a learned society for all categories of Membership. This article briefly describes how the South Australia/Northern Territory Chapter of the AGS has fulfilled these aims.

1 ADVANCING THEORY AND PRACTICE

The problem of cracked houses in Adelaide

The change in volume of a clay arising from change in pore-water content is referred to as reactivity. The change in volume causes movement, distortion and cracking of houses (particularly brick houses) built on reactive clay if they do not have suitable footings. This problem was particularly acute in Adelaide where there are very reactive clays and caused considerable distress to homeowners, builders and engineers.

Suction and suction change in soil under a sealed surface

Early research showed that volume change and shear strength of reactive soil was more closely related to suction (i.e. energy needed to remove porewater from the soil) than water content. During the period 1959 to 1979 the CSIRO Division of Geomechanics, based in Adelaide, undertook a major research program to determine the factors affecting the suction, the change of suction in soils beneath a sealed surface (see Figure 1), and the relation of suction to shear strength and volume of unsaturated clay soils. Outstanding work was done by Dr Gordon Aitchison, Dr Brian Richards, John Woodburn, P Peter and R Martin.

During this time similar research was being conducted in South Africa and Texas (USA) where cracking of houses built on clay also occurred. The results of this research were presented at several important conferences: the International Research and Engineering Conference on Expansive Clay Soil (Texas, USA, 1965) and the 7th International Conference on Soil Mechanics and Foundation Engineering, (Mexico City, 1969); and in important publications such as "Moisture Equilibria and Moisture Changes in Soils Beneath Covered Areas", produced by the CSIRO Division of Soil Mechanics and CSIR South Africa, and edited by Gordon Aitchison, the leader of the CSIRO Division of Soil Mechanics.

A committee of the SA Division of Engineers Australia, comprising several AGS members, was formed to synthesise all this work into a document suitable for engineers designing footings for houses on reactive soil. In 1972 it released the "Guidelines for Members Providing Advice on Domestic and Small Buildings Particularly in Relation to Footings and Foundations". These guidelines were revised and re-released in 1979, becoming popularly known in SA as "the orange book". The committee comprised engineers from the state government, the private sector, the CSIRO, and the University of Adelaide, many of whom were AGS members. At the time "the orange book" represented world-leading practice for the design of footings on reactive soil.

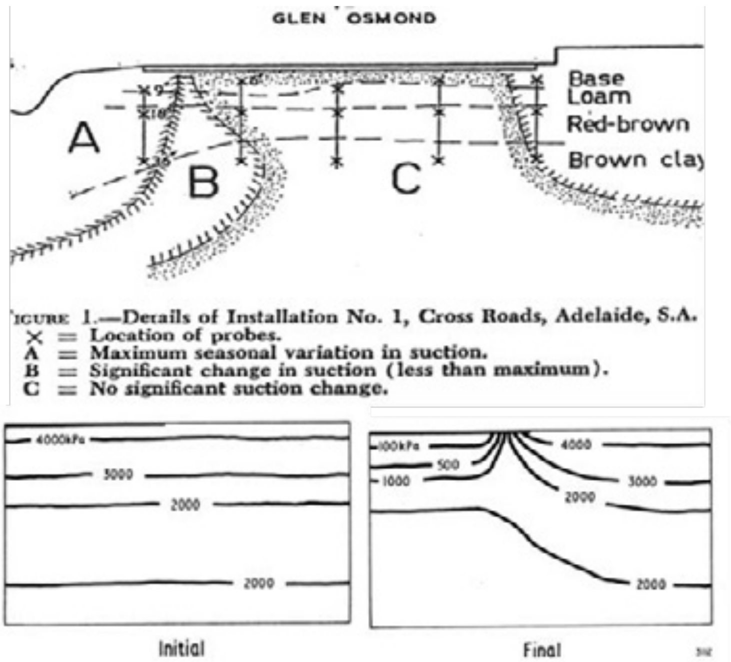


Figure 1: Measured suction profile under a sealed road and early computer modelling of suction profile before and after sealing the ground surface

Figure 2: Title page of K W G Smith & Associates Research Report No 1 by P W Mitchell. This report described the "Mitchell Method" for design of footings for houses on reactive soil

At this time the Footings Group was formed to improve practice in the design of footings on reactive soils by promulgating improved laboratory testing methods and more rational design methods. The Footings Group creates and administers the state-of-the-art document "Special Provisions for the Design of Residential Slabs and Footings for South Australian Conditions".

The Footings Group is a special group within Engineers Australia. Some of its members are also members of the AGS.

The design of footings for small buildings on clay soil

During the period from the late 1960s to the mid-1980s research was performed into the design of footings that were stiff and strong enough to ensure that the distortion of a house built on the footing was reduced to the point where there was negligible damage to the house superstructure. It became apparent that a reinforced concrete slab stiffened by a grid of reinforced concrete beams was a cost-effective solution. Important contributions to the analysis and design of stiffened raft footings were made by R Lytton, P J Walsh and J A Woodburn of the CSIRO; J E Holland, J Washusen and D A Cameron of Swinburne College of Technology Victoria; R A Fraser and L J Wardle of the University of NSW; and P W Mitchell of Kenneth W G Smith and Associates, an Adelaide based consultancy. The results of this work were presented at the 4th and 5th Conferences on Expansive Soils, the 5th conference being held in Adelaide in 1984.

In the period from 1979 to 1986 committees in South Australia and several other states worked to devise a national standard for footing design. This work was organised into an engineering standard by a committee of Standards Australia and culminated in the issuing of AS2870 Residential Slabs and Footings in 1986. Largely through the work of the Footings Group this code has since been revised to allow for the effect of trees on soil movement and footing design.

Advances in testing of soil insitu

In the 1970s it was realised that testing of soil insitu could give more accurate information about soil strength and stiffness and be more cost-effective. In South Australia during the 1980s the use of the electric cone penetration test, the screw plate load test and the Marchetti Flat Plate Dilatometer, was promoted by Dr J N Kay (then senior lecturer, Dept of Civil Engineering, University of Adelaide) and used in engineering projects by P Mitchell, D Avalle, and R Cavagnaro, all AGS members.

2 SHARING THE KNOWLEDGE

Design of footings for houses on reactive soil

During the period from 1970 to 1986 AGS SA/NT was instrumental in promulgating information about footing design for reactive soil and insitu testing by organising a series of events, e.g.:

- Symposium on Soils and Earth Structures in Arid Climates (Adelaide 1970).
- 5th International Conference on Expansive Soils (Adelaide, 1984). The Mitchell method for footing design was presented at this conference.
- Forum on Footing Design for Expansive Soils (Adelaide, August 1985).
- Specialty Geomechanics Symposium (Adelaide 1986).
- 7th ANZ Conference on Geomechanics (Adelaide 1996).

These events attracted attendees and presenters from overseas and interstate.

The shear strength of unsaturated clay

Over the last 20 years the shear strength arising from suction in unsaturated clay has been quantified. Over this period the SA/NT Chapter has arranged meetings and seminars on the topic of shear strength of unsaturated soil and its application for designing more cost-effective earthworks and retaining structures.

Figure 3: Six metre high revetment in unsaturated clay on the eastern approach to the Goodwood rail underpass

Figure 4: Light-weight soil nail/sprayed concrete retaining walls up to 10m high on the Torrens to Torrens Project

3 IMPORTANT PAPERS

YEAR	TITLE	AUTHOR(S)	PUBLICATION
	Understanding the behaviour of unsaturated clay		
1952	The suction of moisture held in soil and other porous materials	D Croney, J D Coleman and W P M Black	D S I R Road Research Paper No 24
1957	The strength of quasi-saturated and unsaturated soils in relation to pressure deficiency in the pore water	G D Aitchison	Proc 4th Int. Conf. Soil Mech. Vol 1, pp135-139
1960	Effective stress in soils, concrete and rocks, pore pressure and suction in soils	A W Skempton	Proc. of Pore Pressure and Suction in Soils Conference, ISSMFE, London
	Relationships of moisture stress and effective stress functions in unsaturated soils	G D Aitchison	
	Mapping the soils of the Adelaide Metropolitan region		
1947	Soil survey and foundation report of an area at Clovelly Park, South Australia	N/A	For the War Service
1950	Soils and soil conditions in relation to the design of the foundations of domestic buildings	G D Aitchison Thesis	University of Adelaide
1954	The soils and geology of Adelaide and suburbs	G D Aitchison, R G Sprigg and G W Cochrane	Bulletin No 32 Geological Survey of South Australia, Department of Mines, SA.
	Soil suction and climate		
1948	An approach towards a rational classification of climate	C W Thornthwaite	Geological Review, Vol 38, p55
1952	The estimation of vertical moisture distribution with depth in unsaturated cohesive soils	Road Research Lab. RN/1709JDC.DC D.S.I.R., UK (Unpublished)	
1956	The circumstances of unsaturation in soils with particular reference to the Australian environment	G D Aitchison	Proc. 2nd Aust-NZ Conference on Soil Mechanics p173-191
1961	The effect of climatic factors on subgrade moisture conditions	K Russam and J D Coleman	Géotechnique Vol 11 (1)p p22-28
	Suction and suction change under a sealed surface		
1965	Moisture equilibria and moisture changes in soils beneath covered areas	G D Aitchison (ed)	CSIRO Soil Mechanics Division and CSIR South Africa Butterworths (Australia)
	Engineering effects of moisture changes in soils	S J Buchanan and G D Aitchison	Proc. Intern'l Research and Eng. Conf. on Expansive Clay Soils, Texas
	Measurement of the free energy of soil moisture by the psychrometric technique using thermistors	B G Richards	Moisture Equilibria and Moisture Changes in Soils Beneath Covered Areas; A Symposium in Print, G D Aitchison (ed.), Butterworth
1969	Soil suction in foundation design	G D Aitchison and J A Woodburn	Proc 7th Internat'l Conf. on Soil Mech. and Foundation Eng. Mexico City
1973	Theoretical transient behaviour of saturated and unsaturated soils under load and changing moisture conditions	B G Richards	CSIRO, Div. of Applied Geomechanics, Tech. Paper No. 16
	The design of footings for small buildings on clay soil		
1973	Design and performance of mat foundations on expansive clay	R L Lytton and J A Woodburn	Proc. 3rd Int. Conf. on Expansive Soils, Israel
1975	Residential raft slabs	J E Holland, J Washusen and D A Cameron	Proceedings Seminar, Swinburne College Press
	The analysis of stiffened raft foundations on expansive soil behaviour and their application to geotechnical structures	R A Fraser and L J Wardle	University of NSW, pp 89-98
1978	The analysis of stiffened rafts on expansive clays	P F Walsh	CSIRO Division of Building Research, Technical Paper No. 23 (Second Series)

YEAR	TITLE	AUTHOR(S)	PUBLICATION
1979	The structural analysis of footings on expansive soil research	P W Mitchell, K W G Smith & Associates	Report No 1, Newton, SA
1980	The structural analysis of footings on expansive soil	P W Mitchell	4th International Conference on Footings on Expansive Soil, Denver, Col, USA
	The development of AS2870		
1979	Footings and foundations for small buildings in arid climates with special reference to South Australia: a basic text for practising engineers		Edited by Philip J Fargher, John A Woodburn and Jonathon Selby
1984	The design of shallow footings on expansive soil	P W Mitchell	PhD Thesis, University of Adelaide.
	An engineering approach to the design of footings on expansive soil	P W Mitchell	Proc 5th International Conference on Expansive Soils, Adelaide, South Australia
	A technique to predict expansive soil movements	P W Mitchell and D L Avalle	
1985	Forum on Footing Design for Expansive Soils		AGS-SA Chapter
1986	Special Provisions for the Design of Residential Slabs and Footings for South Australian Conditions	SA Division Footings Group	IEAust
	Further development of AS2870		
1987	The waffle pod footing system	P S Koukourou and P M Bayetto	Fourth National Local Government Engineering Conference
1995	A probabilistic approach to the design of residential foundations on expansive clays	J A Leach, M B Jaksa and P W Mitchell	Proc Conf. "Buildings and Structures Subject to Ground Movement" Newcastle Feb., pp 169-177
	Field study and back-analysis of a concrete slab footing on expansive soils	J Li, D A Cameron, P M Bayetto and J C Goldfinch	Civil Eng. Trans., IEAust., Vol CE37(1), pp 21-27
1997	The design of residential slabs and footings	P F Walsh and D A Cameron	Standards Australia, HB 28
2006	The influence of trees on expansive soils in Southern Australia	D A Cameron	(Chap. 21) Expansive Soils: Recent Advances in Characterization and Treatment, Al-Rawas & Goosen (eds.), Routledge, 295–314

4 AGS SA/NT MEMBERS MAKING OUTSTANDING CONTRIBUTIONS

Several members of the SA Chapter of the AGS have rendered outstanding service to the AGS and the practice of geotechnical engineering. Dr P W Mitchell has made about 100 presentations to AGS Chapters over a 50-year period. He has served as chair of the national and the state committee and chaired the organising committee of the 5th International Conference on Expansive Soils held in Adelaide in 1984. He devised the Mitchell method for design of house footings on reactive soil. His achievements were acknowledged by the Geotechnical Practitioner Award in the Year 2008.

Prof M B Jaksa has held the position of national and state committee chair. He chaired the committee of the SA Chapter that organised the 7th ANZ Conference on Geomechanics (Adelaide 1996).

He was Australian Vice-President of the ISSMGE (2013-17) and was part of the team successfully bidding for the ICSMGE to be held in Sydney in 2021

5 ONGOING ACTIVITIES AND THE FUTURE

The SA /NT Chapter of the AGS organised the inaugural Geology for Engineers Course in 2002 and continues to run soil and rock logging courses as well as field trips and technical presentations. In addition it runs social events to provide opportunities for practitioners to get to know each other and share knowledge.

In 2019 our state chapter held several joint events with the SA branch of the Institution of Civil Engineers of Great Britain. In the past the SA/NT Chapter has run seminars jointly with other professional associations. We intend to continue joint activities to expose our members to a broader range of topics in engineering and more generally, e.g. climate change.

The SA/NT chapter achieved a milestone in 2019 in the form of a full-day tunnelling symposium. This is part of an annual series of themed symposiums aimed at imparting knowledge to, or promoting discussion among, local members. The scope is smaller than that of conferences, which aim to draw in participants from other states or countries. The theme "Tunnelling under Adelaide" was chosen due to the potential for a tunnel solution for part of Adelaide's North-South Corridor, currently in a feasibility study. The symposium was organised in conjunction with the Victorian chapter of the Australian Tunnelling Society; another example of the benefits of inter-society collaboration.

Given the local scope described above, the symposium was a great success, drawing in 100 delegates (sold out), 14 sponsors, 15 presenters including 2 international keynote speakers, and an address by the state minister for transport. For context, the current number of SA/NT members is roughly 110 members. The event serves to illustrate the relevance of the SA/NT chapter to the geotechnical engineering ecosystem, providing local services for local issues and interests, and helping to provide the best possible geotechnical solutions. The symposium concluded with refreshments and networking to further strengthen the sense of community given the rare large gathering of local members.

To ensure a good future for the AGS in SA and NT, we have encouraged more involvement of young engineers and students over the last few years, culminating with Michael Crisp, a student in the final year of his PhD, being elected our chair in January 2019 at 25 years of age. This year Michael and our committee ran a very successful student/engineer networking event jointly with the SA branch of the Institution of Civil Engineers of Great Britain. We plan to hold these networking events annually so that engineering students can meet practising engineers and find out more about careers in engineering.

Vignette from *Australian Geomechanics* June 1984

5TH INTERNATIONAL CONFERENCE ON EXPANSIVE CLAYS

The 5th International Conference on Expansive Clays was held in Adelaide from the 21st - 23rd May. Over 150 delegates attended with 26 from overseas.

The conference opened with a welcome from the Chairman of the Organizing Committee, Mr Peter Mitchell and the Vice-Chancellor of the University of Adelaide, Prof. Donald Strauks. The welcome was followed by the Opening Address given by the President of the ISSMFE, Prof. Victor de Mello and the Keynote Address, by Mr Brian Richards. As Monday the 21st was a public holiday viz. Adelaide Cup Day, the afternoon was kept free, with visits to the Adelaide Cup, an Aussie football match and the S.A. Constitutional Museum arranged for those interested.

Seven sessions were arranged for the Tuesday and Wednesday with 64 written papers presented. The discussion periods were very lively and showed the keen interest of the delegates in the subject of the sessions. The Closing Address, following the last session on the Wednesday, was given by the Vice-President for Australasia, Dr Roy Northey. If a conclusion could be drawn from the conference, it would be that the art of engineering structures on expansive clay is now well developed, even though our scientific understanding of these clays has a way to go.

The conference dinner was held at the Hilton International Hotel on the Tuesday evening and over 160 guests attended. The President of the Australian Geomechanics Society, Prof. Harry Poulos spoke on the Society and the S.A. Minister of Education and Technology gave the Main Address.

On the Thursday, following the conference, a bus tour was organized to the problem soils of the north-eastern suburbs of Adelaide and the Barossa Valley, where a visit to the Winery at Seppeltsfield was followed by a pleasant lunch in the wineries' dining room. On the return to the city, via the Torrens Gorge, a short visit was made to the CSIRO, Division of Soils Laboratories.

This article was prepared by Richard A Herraman

Right: Vignette from *Australian Geomechanics* March 2002 David Stapledon and some of the attendees at the Geology for Engineers course held in Adelaide on January 2002 inspect a rock outcrop

Vignette from *Australian Geomechanics* June 1986

EDITORIAL

This is the first issue under the auspices of the South Australian Group and I would like to take the opportunity to pay tribute to the sterling work over the past two years of the Sydney Group, in particular John Small and John Carter and in the case of the latter John over the past several years! Having been now involved in the production of one issue I can appreciate the time and effort required by the editorial panel.

This is also the first issue under the title "Australian Geomechanics". This change was approved by the National Committee to reflect the change in status of the publication since its original inception as a "Newsletter". However, the sub title "News Journal of the Australian Geomechanics Society" will remain unchanged.

The other change relates to advertising. We are considering whether to accept commercial advertising in "AG". The revenue would be directed to defraying Society costs and holding down subscriptions. Views of State Groups, supporting members and individual members are wanted - to the Society Secretary in Canberra please.

The Journal has been in production for over 5 years and has become firmly established as a useful and readable publication. I believe one of its strong points is that it provides a venue whereby authors can publish material in a reasonably quick time and this is important in the Geomechanics profession where new developments are continually occurring.

THE EDITORIAL PANEL

Bob Newman   Bill Boucaut   John Beal

I would like to here raise a topic which will be followed up in later issues. A quick review of past papers indicates a good coverage of the "successes" in the field - what about the "failures" or "partial successes"? Surely there is as much or more to be learned by everyone from these latter two. I appreciate it is difficult to admit publicly that we are not all perfect, however I would ask you give some consideration to providing articles, possibly under "Micros and Minis" where examples can be given of unexpected occurrences at the testing stage, or during or after construction. These must be of benefit to the profession as a whole and also to the community in general in the longer term. The topic was also raised by the Victorian Group in a letter to the Editor by their Chairman, Bill Bamford in the December 1984 issue ending with a similar wish "Please be courageous enough to share these most educational experiences with your colleagues". Perhaps the Victorian Group would like to kick-off with the first case history! The recording of failures and what we can learn from them is also very relevant in the light of Dr Barry McMahon's E.H. Davis Memorial Lecture "Geotechnical design in the face of uncertainty" - obligatory reading if you are not fortunate enough to be present at his lecture.

John Small in his swansong editorial hinted at the new editors having "some innovative and exciting ideas". I hasten to add that this does not involve any drastic changes to the Journal but the S.A. Group believes there should be more direct involvement of you the reader. We would like to see the raising of issues of significance to the Geomechanics profession either by articles or "Letters to the Editor" and subsequently for others to voice their opinions. This would give people in the workplace the opportunity to express their views on these issues and I am sure this would be of assistance to the National Committee in their deliberations.

Thus it is fitting that the first of these "issues" is raised by the Chairman Dr Peter Mitchell. The legal responsibilities of the profession are becoming more and more important and thus Peter's guest editorial is timely and thought-provoking.

The Editorial Panel looks forward with enthusiasm to the next 18 months and we would hope your enthusiasm would result in pen being put to paper. We will accept all contributions (other than formal papers) in any form - handwritten on tearoff paper will do.

Bill Boucaut
Editor

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Vignette from *Australian Geomechanics* March 2018

CHAPTER NEWS

SOUTH AUSTRALIA / NT

PROF MARK JAKSA RECOGNISED FOR SERVICE TO AGS

A memento was given to Mark Jaksa during the AGM of the SA/NT Chapter last year in appreciation for his service to the AGS.
Mark has an amazingly impressive history of voluntary work for the AGS and service to the geotechnical profession as a whole. The list given below shows the various participatory and leading roles within AGS that Mark has had over the last 25 years.

Congratulations and thank you, Mark!

Affiliations

- Member, Institution of Engineers, Australia. (MIE.Aust. CPEng)
- Member, Australian Geomechanics Society
- Member, International Society for Soil Mechanics and Geotechnical Engineering
- Faculty Member, ASFE: Professional Firms Practicing in the Geosciences
- Member, S.A. Footings Group.

Activities

Current:

- 2002-Present: Committee Member, ASCE GI-RAM (Geotechnical Institute, Risk Assessment and Management)
- 2002-Present: Member, Chapter Committee, Australian Geomechanics Society (S.A. Chapter)

Former:

- 2013-2017: ISSMGE Vice President for Australasia and Treasurer
- 2010-2013: ISSMGE Liaison, National Committee, Australian Geomechanics Society
- 2006-2010: Core Member, Joint Technical Committee 3 (JTC-3), Joint
- Committee on Education and Training, ISSMGE, IAEG, ISRM
- 2006-2007: Immediate Past Chair and Treasurer, National Committee, Australian Geomechanics Society
- 2004-2005: Chair, National Committee, Australian Geomechanics Society
- 2002-2003: Deputy Chair and Treasurer, National Committee, Australian Geomechanics Society
- 2002-2010: Member, Technical Committee 32 (TC32), Engineering Practice of Risk Assessment and Management, ISSMGE
- 2000-2005: Member, Technical Committee 31 (TC31), Geotechnical Engineering Education, ISSMGE
- 2002-Present: Member, Chapter Committee, Australian Geomechanics Society (S.A. Chapter)
- 1999-2013: Webmaster, Australian Geomechanics Society
- 1999-2006: Webmaster, Australian Geomechanics Society (S.A. Chapter)
- 1999-2001: SA/NT Representative, National Committee, Australian Geomechanics Society
- 1999: Sepang Inst. Tech., Liaison, Dept. Civil & Env. Eng.
- 1997-2001: Chair, Australian Geomechanics Society (S.A. Chapter)
- 1996-1999: Associate Dean (Facilities), Faculty of Engineering, Computer and Mathematical Sciences
- 1994-1996: Chair, 7th Australia New Zealand Conference on Geomechanics (Adelaide) Local Organising Committee
- 1994-1996: Secretary, Australian Geomechanics Society (SA Chapter)

Professor Mark Jaksa (L) receives trophy from Shane Wynne, Chair of SA & NT chapter (R)

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SOUTH AUSTRALIA AND NORTHERN TERRITORY CHAPTER

SA and NT CHAPTER COMMITTEES

Year	Chairman	Deputy Chairman	Secretary	Treasurer	National Representative
1970-72					Mr David Stapledon Mr Steve Wawryk Mr M Wood
1973					Mr Doug Inkson
1974 - 75	Mr R Perry		Mr Steve Wawryk		
1976 - 77	Mr John Woodburn				Mr John Woodburn
1978					Mr Charles Fitzhardinge
1979 - 80					Dr Peter Mitchell
1981	Mr Bill Boucaut		Mr Bob Newman		
1982					Mr Brian Richards
1983	Mr Bill Boucaut				
1984-86	Dr Peter Mitchell	Dr Neil Kay	Mr Bob Newman		Dr Neil Kay
1987	Dr Neil Kay	Mr Brian Richards			
1988 - 89	Mr Brian Richards	Mr John Morris			Mr Brian Richards
1990					
1991	Mr Bob Newman		Dr Patrick Lun		Mr Bob Newman
1992-93		Mr John Morris			
1994	Mr Charles Fitzhardinge	Mr Don Cameron	Mr Mark Jaksa		Mr Don Cameron
1995			Mr Don Cameron		
1996	Mr Don Cameron		Dr Mark Jaksa	Mr Richard Herraman	
1997	Dr Mark Jaksa		Dr Matthew Duthy		
1998	Dr Mark Jaksa				
1999			Mr Don Richardson		Dr Mark Jaksa
2000-01			Mr Roger Grounds		
2002	Mr Richard Herraman			Mr Richard Cavagnaro	Mr Richard Herraman
2003-05	Dr Matthew Duthy	Mr Brenton Harris	Mr Brenton Harris		Dr Matthew Duthy
2006	Mr Mark Drechsler	Mr Richard Herraman	Mr Richard Herraman	Dr Anthony Meyers	Mr Mark Drechsler
2007			Dr Aaron O'Malley		
2008	Mr Brenton Harris	Mr Mark Drechsler		Mr Richard Herraman	Mr Brenton Harris
2009			Mr Derek Arnott	Dr Anthony Meyers	
2010	Dr Matthew Duthy	Dr Aaron O'Malley	Mr Brendan Scott		Dr Matthew Duthy
2011				Mr Brendan Scott	Mr Brendan Scott
2012	Dr Aaron O'Malley	Mr Derek Arnott	Mr Mark Argent	Dr Matthew Duthy	
2013	Mr Derek Arnott	Mr John Slade			Mr Derek Arnott
2014			Mr Richard Herraman	Mr Brendan Scott	
2015	Mr John Slade	Mr Mark Argent		Dr Matthew Duthy	Mr John Slade
2016		Mr Shane Wynne		Mr Stuart Cowan	
2017	Mr Shane Wynne	Mr Mark Argent			Mr Shane Wynne
2018			Mr Stuart Cowan	Mr Richard Herraman	
2019	Mr Michael Crisp	Dr Abbas Taheri			Mr Michael Crisp

1980 TO 1989

NEW FOUNDATIONS

Owning a home has long been the Australian dream, and the housing industry remains a leading sector in the Australian economy. Most of Australia's major cities are built on reactive (expansive) clays which manifests in many and varied ways across our wide land. Australian scientists and engineers, mostly working for the CSIRO, led the world in the 1960s and 1970s in reactive and unsaturated soils research. This research reached its peak in the 1980s, leading to the release of AS2870, Residential Slabs and Footings in 1986; the first national standard for foundation design on reactive clays to be adopted anywhere in the world.

Cracked house in Adelaide
Photograph courtesy FMG Engineering

PETER HOLLINGSWORTH AO CHAIR 1979-81

> I was asked what project over my career had greatest impact on me and I must say that it was the Bougainville copper mine in Papua New Guinea. Coffey and Hollingsworth conducted geotechnical investigations and materials testing there in the late sixties and early seventies. The project was very successful.

1980-1989

It is no mean thing to be asked to recollect events from forty years ago, and I have not been able to do that, without memory jogging help from events reported in editions of Australian Geomechanics during my term as Chair.

My general recollection of the National committee was that we were always busy. Personally, I was busy representing the AGS on various task forces– including the Task force on National Disasters, Working Party on Offshore Codes of Practice and the Working Party to consider the implication of a 200 mile exclusion economic zone around Australia.

A special international visitor in 1980 was Professor Branko Ladanyi of the University of Montreal, Canada. Professor Ladanyi presented the keynote address at the International Conference on Structural Foundations on Rock in May. He also addressed many local groups, before travelling to Wellington for the 3rd ANZ Geomechanics conference being held in Wellington New Zealand. I have a vague memory of attending that!

The following year, in March 1981, the 4th Australian Tunnelling Conference was held in Melbourne.

In February 1981 Ted Davis, a towering figure in our soil mechanics world, died suddenly. It was a great loss to our community.

Recollections of Peter, by others:

Allan McConnell and David Williams both recall that Peter Hollingsworth would frequently co-opt the monthly AGS meetings – where he would turn up to QLD Group events with a box full of slides and wait until the call for "any further questions" rang out.

Apparently, Peter would reply with "I've got one" and proceed to make a short, albeit very entertaining, presentation about a completely different topic – including his recent experiences with scuba diving with sharks, bamboo farming in the Brisbane Valley and crossing rivers whilst dodging crocodiles during the development of a new mine in PNG.

2 NATIONAL COMMITTEE REPORT

Introduction

The Australian Geomechanics Society, with 362 financial members, is somewhat different from other National Committees associated with the Institution of Engineers, Australia.

Firstly, it is jointly sponsored by the Institution of Engineers and the Australasian Institute of Mining and Metallurgy.

Secondly, there are three very active international societies which look after the learned society activities in Geomechanics. They are:

The International Society for Soil Mechanics and Foundation Engineering (ISSMFE).
The International Society for Rock Mechanics (ISRM).
The International Association of Engineering Geology (IAEG).

Australia and New Zealand are considered to be the Australasian region for these societies. The region is represented on the governing bodies of these by a Regional Vice President who is nominated by the Australian Geomechanics Society and the New Zealand Geomechanics Society on the preferred basis of two Australian Vice Presidents to one New Zealand Vice President.

The present Vice Presidents are:

I.S.S.M.F.E. - Mr. A. Hosking
I.S.R.M. - Mr. W. Bamford
I.A.E.G. - Professor D. Stapledon.

Each International Society holds an International Conference in its speciality every four years, and each Region holds one or more conferences in the specialities every four years also. The Australasian Region holds one conference, the Australia-New Zealand Geomechanics Conference to cover all three specialities.

Thirdly, for several reasons, particularly its joint sponsorship, the committee structure is different from other National Committees.

The Committee membership is as follows:

Chairman	Mr. P.C. Hollingsworth - Consulting Engineer
Deputy Chairman	Dr. C.M. Gerrard - C.S.I.R.O.
Immediate Past Chairman	Mr. W.E. Bamford - University of Melbourne
Vice President, ISSMFE	Mr. A.D. Hosking - Consultant
Vice President, ISRM	also Mr. W.E. Bamford - University of Melbourne
Vice President IAEG	Professor D.H. Stapledon - S.A. Institute of Technology
Two members nominated by I.E. Aust	Mr. I. R. Jamieson - Consulting Engineer Professor I.B. Donald - Monash University
Two members nominated by AUS. I.M.M.	Mr. G.B. Connor - A.M. & S. Broken Hill Mr. F.E. Kaesehagen - M.I.M. Queensland
Elected by members in New South Wales & A.C.T.	Dr. H.G. Poulos - University of Sydney Mr. D. Inkson - Consulting Engineer
Elected by members in Victoria and overseas	Dr. I. Johnston - Monash University Mr. W.L. Pump - C.R.B. of Victoria
Elected by members in Queensland	Mr. B.T. Boyce - Queensland Institute of Technology
Elected by members in South Australia and Northern Territory	Mr. P. Mitchell - Consulting Engineer
Elected by members in Tasmania	Mr. G.T. Roberts
Elected by members in Western Australia	Dr. B. Clegg - University of Western Australia

Fourthly, the A.G.S. carries out a number of tasks and functions which differ from other National Committees. These include:

It permits membership of one or more international societies which in turn allow attendance at international conferences and receipt of international publications.
It provides reduced prices for attendance at seminars and conferences including international conferences.
It selects and monitors Australian representation on working subcommittees and commissions of the three international societies.
It organises international conferences (presently organising the ISRM Congress, Melbourne 1983 and the 4th Australia-New Zealand Geomechanics Conference, Perth 1984).
It has a professional responsibility to be involved in continuing educational activities.
It has an interdisciplinary function allowing the mixing of engineering geology, soil science, mining engineering, and soil and rock mechanics.
Following its recent review of members' needs, the committee has replaced the Australian Geomechanics Journal by the Australian Geomechanics News to be published twice annually.
It promotes overseas speakers and arranges their visits to Australia.
It provides a means for members to keep abreast of the latest professional matters.
It arranges visits to construction and mining sites.

Fifthly, because of its interdisciplinary function it allows for memberships from engineering geology, soil science and specialists related to mining processes who are not members of the Institution or the Institute.

Sixthly, because of the broad range of extra functions it is necessary for the Australian Geomechanics Society to charge an extra fee to members who are also members of the Institution or the Institute. These two sponsors contribute funds to the running of the Society on behalf of their members. It is therefore necessary for the Society to charge a higher fee to members of the Society who are not members of the sponsoring bodies.

<u>Australian Geomechanics Award</u>

The Australian Geomechanics Award was instituted during the year. It is called the John Jaeger Memorial Medal. The inaugural medal was won by Professor Ted Davis of Sydney University and presented to him at the 3rd Australia-New Zealand Geomechanics Conference in Wellington in May.

Vignette from *Australian Geomechanics News* December 1980

PROFESSOR HARRY POULOS AM CHAIR 1982-84

> I recall these years as a period of consolidation of AGS, and a time of collegial cooperation among a growing band of geotechnical devotees. I would also like to think that Australia's visibility on the international geotechnical stage continued to grow.

I had the honour of being Chairman of the AGS for the period 1982 to 1984, after a relatively short time on the National Committee. I have set out below a few of my recollections of this period, largely via a failing memory and a very limited amount of personal documentation.

During this period, the committee consisted of enthusiastic and dedicated representatives from the various state groups, and representatives from the sponsoring organizations. The National Committee line-up in 1982 was as follows:

Chairman:	Harry Poulos
Deputy Chair:	Peter Mitchell
Immediate Past Chairman:	Peter Hollingsworth
Vice President ISRM:	Bill Bamford
Vice-President IAEG:	David Stapledon
IE Aust nominated:	O.A. Willson
	Neil Mattes
Aus IMM nominated:	R.E. LeMesurier
	F.E. Kaeshagen
NSW & ACT members:	John Small Philip Pells
Victoria and overseas:	Warren Pump
	J.A. Washusen
Queensland:	Neil Robertson
South Australia & NT:	Brian Richards
Tasmania:	B.A. Cole
Western Australia:	John Trudinger
Secretary:	John Harding

The AGS membership at that time consisted of 427 members, of which 259 were affiliated with ISSMFE, 248 with ISRM, and 215 with IAEG.

My time as Chairman had started off in the shadow of the previous year when my mentor and colleague, Professor Ted Davis, died in February of a heart attack, aged only 60. The sense of loss that I, my Sydney University colleagues, and the Australian geomechanics community felt was very great. Ted had delivered the inaugural Jaeger Memorial Lecture at the ANZ Conference in Wellington a few months earlier, and had revealed the early stages of his research into the extension of plasticity theory to structured soil and rock masses. However, he left a substantial legacy through his colleagues and research students, several of whom have gone on to make their own marks in the geotechnical world.

There were two major conferences in Australian geomechanics during my chairmanship. The first occurred in April 1983, when Australia hosted the 5th International Congress in Rock Mechanics in Melbourne. This was the first time that Australia and the AGS had been successful in bidding for an international geotechnical conference. It was also notable for Australia's Professor E.T. (Ted) Brown being elected as ISRM President.

The second was in May 1984, when Perth hosted the 4th Australia New-Zealand Conference on Geomechanics, with the theme "Geomechanics – Interaction". At that conference, the Jaeger Memorial Lecture was delivered by Dr Gordon Aitchison, who gave a broad outline of his research on unsaturated soils. A feature of that conference was the keynote lecture given by Professor Victor de Mello on "Concrete Gravity Dam Foundations: an Open Case of Geomechanical Interaction, Structure - Foundation and Theory - Practice". De Mello was President of ISSMFE at that time, and was the first President to visit Australia while in office. He also visited Sydney and Melbourne during his visit. Figures 1 and 2 show photos taken during the de Mello's visit to Sydney.

At the Perth Conference, it was decided to hold the 5th Australia-New Zealand Conference on Geomechanics in Sydney, and I had the dubious honour of being appointed the chair of the Organizing Committee.

Another noteworthy technical event was an extension course on "In-situ testing for geotechnical investigations", organized by the Sydney group in 1983. This led to the publication of a volume edited by Max Ervin and published by Balkema, one that was widely referred to in subsequent years.

Figure 1: Maria-Louisa de Mello, Victor de Mello and Maria Poulos enjoying the view from the Gap, Sydney, 1984

Figure 2: Maria-Luisa de Mello, Harry Poulos, Victor de Mello and Peter Mitchell at the 4th ANZ Conference in Perth, 1984

1980 marked a watershed in geomechanics and geotechnical publications in Australia. Prior to the formation of AGS in 1970, the main outlets for publications by Australian authors were the Transactions of the Institution of Engineers Australia, or a limited number of overseas journals, primarily Geotechnique in the UK, the Journal of the Soil Mechanics and Foundations Division of the American Society of Engineers, and from 1964 onwards, the Canadian Geotechnical Journal.

With the formation of AGS in 1970, it was decided that the Society would publish its own journal, the Australian Geomechanics Journal. Dr Ian Donald of Monash University undertook the inaugural editorial role, and this journal was published annually from 1971 to 1979. A number of influential papers appeared in the journal during this time.

Because of difficulties encountered in obtaining papers of suitable quality on a timely basis, AGS decided to cease publication of the journal, and instead, to produce a more informal publication entitled "Australian Geomechanics".

This has proved to be a master stroke, and through the efforts of a series of dedicated editors, this publication now appears four times yearly, and contains both news and an excellent variety of technical papers. A particularly influential volume was published in 2007 and dealt with Landslide Risk Assessment. "Australian Geomechanics" continues to be one of the major benefits of AGS membership 40 years after its inception.

The general situation regarding publications during my term as AGS Chairman is set out in an early editorial that I contributed to Issue 4 of the Australian Geomechnics News, 1982, and which is reproduced below, in the original font.

One of the objects of a learned society is to disseminate information to its members and thereby stimulate thought, discussion and criticism. In engineering circles, there are several instances in which this function is fulfilled in a very efficient manner. For example, the American Society of Civil Engineers caters for a wide variety of disciplines within civil engineering by publishing separate journals at frequencies ranging between one and three months.

In addition, it publishes a monthly journal devoted to more general topics of technical and commercial interest and a monthly newsletter outlining technical activities of the Society.

This happy situation contrasts sharply with ours in Australia. Civil engineers belonging to the Institution of Engineers, Australia have only a single technical outlet, the Transactions, which appears twice yearly and has to serve all disciplines within Civil Engineering. True, we have "Engineers Australia", which has proved to be a great success, but is essentially a news and information magazine rather than a technical journal. Until 1979, members of the Australian Geomechanics Society were in the fortunate and unique position of having their own journal (albeit a once yearly publication), but because of financial considerations, the luxury of the Australian Geomechanics Journal was dispensed with, and the geomechanics fraternity returned to par with the less-fortunate engineers in other areas of Civil Engineering. Fortunately, a hard working group of people based in Victoria managed to put together, with much effort and copious amounts of voluntary labour, the Australian Geomechanics News, the first issue of which was published in December, 1980. This publication, while not attempting to replace the late Geomechanics Journal, has nevertheless provided a means of technical communication between members of the Australian Geomechanics Society and has succeeded in keeping those members informed of current events and developments, both in Australia and overseas.

This present issue is the fourth and is being produced by a volunteer group in Queensland, following the production of the first three issues in Victoria under the editorial care of Dr Ian Johnston. It is perhaps premature to attempt to properly evaluate the impact and usefulness of the News after only three issues. However, my discussions with a number of people lead me to believe that the general concept of the News is appreciated, that it is conveying useful technical and nontechnical information to its readers, and that A.G.S. members feel they are getting at least some tangible return for their membership fees. Speaking personally, the News has exceeded my expectations, and I have found the technical notes to be particularly useful in providing both a concise statement of work done in certain problem areas and references for those who wish to delve more deeply into the finer points of the topic.

It is in the publication of Technical Notes that I see further scope for the development of the Australian, Geomechanics News as a medium of technical communication. We must accept, for the time being at least, that Australia cannot support a viable technical geomechanics journal of its own. As stated by Ian Donald in his Guest Editorial for the first issue, "We seem to store many of our papers for the four-yearly feast, possibly as meal ticket guarantees of conference attendance, or we submit our best research to overseas journals for multifarious reasons, including reaction against our geographical isolation". This leaves us then with the News as our only means of communication between different sections of the geomechanics fraternity (not including the I.E.Aust. and the Aust.I.M.M. publications which are not necessarily taken or seen by all A.G.S. members).

The first three issues of the News have seen a total of six Technical Notes, each one an excellent contribution. Some have come from groups or individuals who have summarised the results of their research work, and at least one has been derived from a talk given to a local branch of the A.G.S. Within Australia, we have in excess of thirty meetings of the Geomechanics Society annually. If only one in three of the speakers were to summarise their talk and submit it as a Technical Note to the News, we would have at least ten contributions per annum, or five per issue.

I would therefore urge local groups of the A.G.S. to make it one of their tasks to seek out and extract technical contributions from members. For, example, in writing to invite a speaker to present a talk, strong encouragement could be made for him to provide a summary of the type mentioned above. Speakers already provide some form of abstract for publication purposes, so that only a relatively small expansion of this abstract would be required, with some additional text and a few key figures added. Local committees could also undertake to directly contact people who they know are involved in interesting projects or research work and directly solicit Technical Notes. It should be emphasised that such notes do not need to be "high-powered", highly original, or of a level which might be considered appropriate for a wholly-technical journal; the main function of a note is to inform the reader of the general nature of the topic and direct him or her to more detailed information sources.

A factor which may inhibit some potential contributors is the stated desirability of Technical Notes being submitted in camera-ready typed form. (It is ironic that, in these days of high technology in the printing industry, we poor engineers and geologists are asked to be our own compositors!) However, I feel sure that the editorial group responsible for the production of the News would be willing to type Technical Notes submitted in draft form from those who do not have appropriate facilities available.

A successful Society relies on co-operation among its members and contributions from individuals for the benefit of the whole membership. Let us ensure that the Australian Geomechanics Society successfully fulfils one of its major functions - technical communication - by making a concerted effort to contribute more technically-oriented material to its "voice" - the Australian Geomechanics News. Your continued and expanded support will see it flourish and grow; otherwise, it may eventually become another casualty of economic expediency, which, together with the late Geomechanics Journal, may condemn the A.G.S. to a moribund future.

I am delighted to report that this gloomy prediction was consistent with some of my other geotechnical predictions, quite inaccurate!

The AGS membership at that time consisted of 427 members, of which 259 were affiliated with ISSMFE, 248 with ISRM, and 215 with IAEG.

FOREWORD

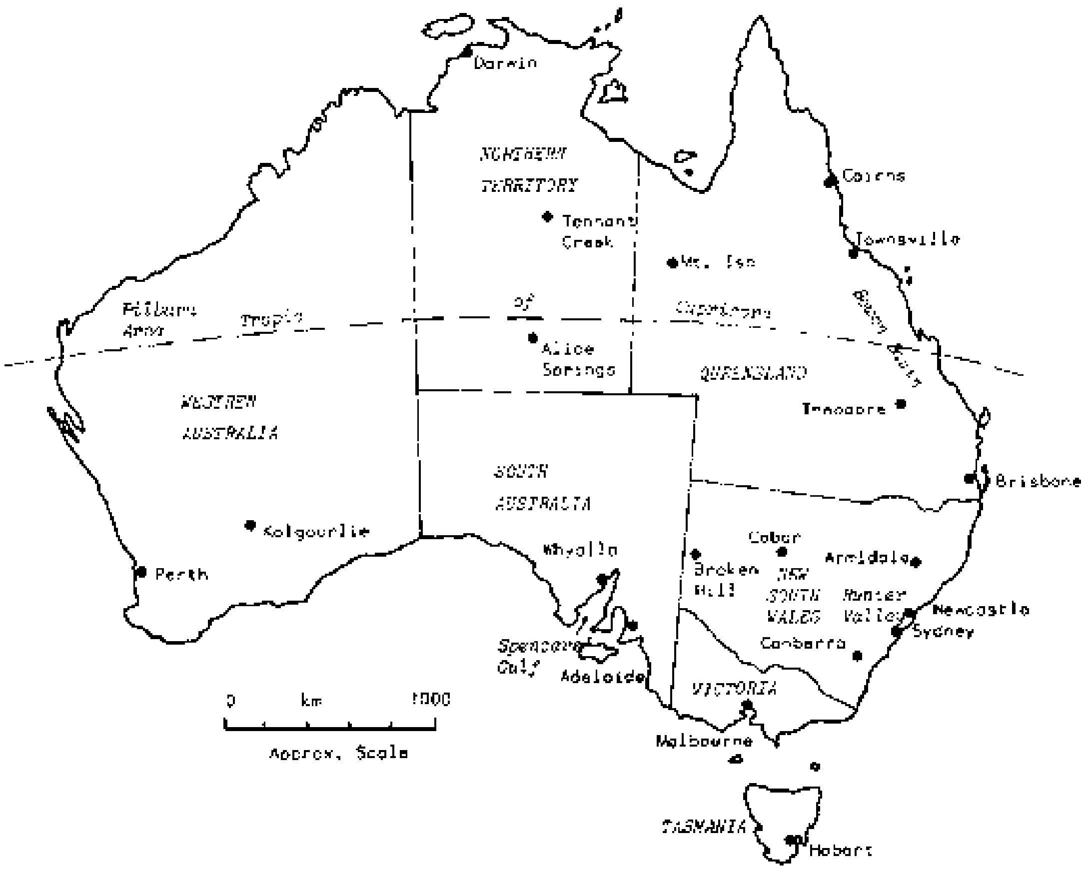
The Australian Geomechanics Society comprise engineers and geologists who are concerned with soil mechanics, rock mechanics and engineering geology. It is affiliated with the International Societies of each of these disciplines. The Australian Geomechanics Society is structured into a number of Groups, broadly on a State basis, because of the size of the country. Centres of development and geotechnical activity are separated by large distances. It is 3,400 kilometres direct distance from Sydney on the east coast of the continent to Perth on the west coast, and 2,000 kilometres from Melbourne to Townsville in North Queensland, from whence Professor Hugh Trollope has contributed the Editorial Article for this publication.

Members are kept informed of the activities of the Society in other areas by means of a news journal, the Australian Geomechanics News. This publication has been prepared after the form of the Australian Geomechanics News for the special occasion of the ISRM Congress. Its aim is to present a cross-section of geotechnical activities in Australia, with perhaps some emphasis on the area of rock mechanics. To this end contributions representative of their activities have been invited from each Group of the Australian Geomechanics Society. For the benefit of overseas readers the originating State has been acknowledged in each contribution. Also, the locations of the States and many of the places mentioned in the following articles may be found on the map below.

This publication is provided to the Delegates at the Congress with the compliments of the Australian Geomechanics Society. Two editions of the Australian Geomechanics News are currently produced each year; you are invited to subscribe to it if you are not already doing so. Subscription details can be found on the title page of this publication.

On behalf of all the members of the Society I wish our overseas visitors a happy and fruitful stay in our country.

H.G. Poulos
National Chairman, AGS.



Vignette from *Australian Geomechanics Special Edition – 5 ISRM*, Melbourne, April 1983

PROFESSOR PETER MITCHELL CHAIR 1985-87

I am proud to have contributed the so-called 'Mitchell method' to AS2870 'Residential slabs and footings'. This design code ensures the use of the principles of geomechanics in the design of residential footings. The standardisation of engineering design procedures means that homeowners now have greater confidence in the integrity of the structure of their home.

The mid 1980s was a period of rapid change for the geomechanics profession, with an increasing sophistication in methods of testing and construction, and with the development of computer-aided design, supported by the advent of the personal computer.

The Australian Geomechanics Society was very active, with a continuing increase in membership and supporting organizations. Members were kept busy being involved in the organization of conferences, with the issue of public statements, involvement in working groups, and liaison with other professional bodies, all undertaken with the aim of promoting the science and practice of Geomechanics in Australia.

The Commemorative Volume, comprising a selection of the best Australian papers (in the opinion of an editorial panel from the AGS committee) over the period 1935 to 1985 was produced for the Golden Jubilee of the International Society for Soil Mechanics and Foundation Engineering at the XI International Conference on Soil Mechanics and Foundation Engineering (ICSMFE) in San Francisco in 1985.

In order to address a widespread and longstanding concern in the construction industry at the difficulties involved in the preparation and provision of geotechnical site information, and the high incidence of disputes over latent conditions, the AGS committee made a significant contribution to the 19 page booklet "Guidelines for the Provision of Geotechnical Information in Construction Contracts", published by The Institution of Engineers, Australia in 1987.

In order to help minimize the future occurrence of problems experienced in some litigation cases in the early 1980s, the AGS committee endorsed the document "Guidelines for Members Reviewing the Work of Other Engineers for the Purposes of Litigation" produced in 1987, and published in the Australian Geomechanics Journal No. 15, pp 127-135 in August 1988.

The Sydney group of the AGS was responsible for the very informative book, Pells P.J.N. (edit) "Engineering Geology of the Sydney Region", Balkema, Rotterdam, published on behalf of the Australian Geomechanics Society in 1985.

During the period 1985 to 1987, an organizing committee formed by the Sydney Group ensured that the Fifth ANZ Geomechanics Conference was successfully held in 1988. Similarly, an organizing committee from the W.A. Group ensured that the International Conference on Calcareous Sediments was successfully held in Perth also in 1988. The Tasmanian Group was involved in the coordination of the Fifth International Conference and Workshop on Landslides in 1987.

Many members of the Australian Geomechanics Society made a significant contribution in various state sub-committees of the Standards Australia Committee BD/25, leading to the publication of the inaugural edition of AS2870 "Residential slabs and footings" code in 1986.

In the report by Max Ervin (AGS chair 1991 to 1993) he makes mention of the AGS bid made in Dublin in 1987 for the 1993 ICSMFE, our competition being India, the successful bidder. Always with conferences in Australia, the issue of travel time and cost are an issue. I clearly remember in our bid presentation, we had a slide of the world showing Australia in the centre of the slide, with Europe and Africa to the left, and the Americas to the right, the implication being that Australia is not all that far away. The Indians presented their bid, and showed a slide of the world with India at the centre of the slide, with Australia pushed over to the lower far right of the slide, with the statement made that "this is where Australia really is in the world". We were convincingly beaten in the vote! Isn't it now ironical that 34 years later in September 2021, Sydney will host the next international conference?

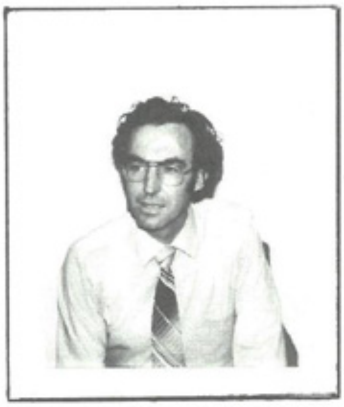
GUEST EDITORIAL

One major problem affecting the practice of Geomechanics in Australia, is that associated with professsional liability. The problem has increased at such a rate in recent years, that it is seriously affecting the conventional practice of our profession. It is an area affecting Geotechnical Engineers perhaps more so than other branches of science and engineering, because of the high risks and uncertainties that are inherently associated with our profession. It is an area mainly affecting the practitioner in private industry at present, but could logically include those involved in government or academic institutions.

Risks in our profession include such aspects as misidentification of soil and rock types, strengths and profiles; mis-identification of filled sites; omissions in design documentation and inspection procedures; incorrect assessment or prediction of groundwater influences and other environmental factors; inadequate site investigation; presence of underground anomalies; to name a few. These instances are often easy to see in retrospect when the problem has become manifested. However, at the design and prediction stage they are often extremely difficult to forsee.

This was recognized at an international level when a full morning session at the 11th International Conference on Soil mechanics and Foundation Engineering held in San Franciso in August, was devoted to this topic. At the conference, the accomplishments of the Association of Soil and Foundation Engineers (ASFE) in the U.S.A. where outlined. The ASFE has developed a variety of professional liability loss prevention programmes and materials in the U.S., and was the subject of a conference paper (Bachner J.P. & Roberts D.V. "The ASFE Story" Proc. 11th Int. Conf. Soil Mechs. & Found, Eng., vol. 4, p. 2283, San Francisco, Aug. 1985).

One of the ASFE loss prevention methods is that of the Quality Control Peer Review program, which is considered one of the organization's most significant contributions to the engineering profession. Through it, a peer review of quality control procedures in Geotechnical firms and departments is undertaken. This procedure is a formal evaluation of a consultant's or department's quality control procedures by outside professionals. Thus it is analogous to the laboratory accreditation procedures currently issued by the National Association of Testing Authorities, Australia.



It is emphasized that this is NOT a review of technical performance, nor a review of the financial affairs of the company or department, but a review of the methods of how the company or department carries out its own methods of minimizing errors and mistakes in their practices. It is carried out to help the profession as a whole.

The S.A. Group, at a committee level, has discussed the possible introduction of this locally. As was encountered in the U.S.A. at first, there was found to be several misgivings to these aspects, mainly because of the understandable reluctance to allow outside professionals having contact with any internal procedures of a practice or department. In the U.S.A. however, with the realization of the great benefits that can result, this reluctance has been largely overcome, so that the peer review of quality control procedures is now widely accepted. It has contributed significantly in reducing the risks associated with the Geotechnical Profession in the U.S.A..

I would urge all State groups to consider the success of this approach in maintaining high standards in quality control procedures in our profession. Naturally, there will be the same difficulties that were encountered in the U.S.A., and as discussed by the S.A. Group, however, the undoubted success of the approach adapted by the ASFE in the U.S. is testimony to its usefulness. It offers one practical way of limiting further development of the litigation problem.

PETER W. MITCHELL
Chairman, Australian Geomechanics Society.

Vignette from *Australian Geomechanics* Number 11 June 1986

CASE EXAMPLES SHOWING THE SUCCESS AND CONTINUING CHALLENGES IN THE USE OF AS2870

Dr Peter W. Mitchell has 48 years of experience in major geotechnical projects throughout Australasia, South-East Asia and the South Pacific. He is an Adjunct Professor at the University of Adelaide and is a past chair of the Australian Geomechanics Society.

He was a 1979 SA Engineering Excellence award winner (IEAust); a 1980 Churchill Fellow; the 2008 Geotechnical Practitioner of the Year awarded by the AGS; and the author of the 'Mitchell Method' referred to in AS2870.

PROFESSOR PETER MITCHELL

Other papers in this book by John Woodburn and Richard Herraman give background information leading to the development of AS 2870 "Residential slabs and footings" first issued in 1986. The greater use of geotechnical design procedures for footings on expansive soil, as codified by AS 2870, has led to a lower incidence of problems associated with expansive soils.

A major reason for this, has been the development of computer based methods of analysis for the footing design process. The two methods recommended by AS 2870 are the Walsh method and the Mitchell method. The Walsh method is used in program CORD and similar computer programs, while the Mitchell method is used in program SLOG. The speed, convenience and reliability of these computer programs has enabled greater acceptance by designing engineers to adopt these methods of analysis.

This article gives an example of a footing design carried out prior to the widespread adoption of the computer based design methods, illustrating the effectiveness of the procedures of AS 2870 in overcoming previous problems. An example of a cracked house with a well-designed footing that was distorted by an extreme soil suction change is used to illustrate the importance of the recognition of 'abnormal moisture changes' by AS 2870. The article is concluded with an example of a house cracked by the effects of nearby trees, illustrating the uncertainties in the design process when considering the effects of trees.

1 CRACKED HOUSE EXAMPLE NO.1

A common problem that existed prior to the advent of computer based designs by AS 2870, was that a stiffened shallow footing, such a raft or a stiffened network of strip footings, did not have adequate gridding. The sub-beams of a raft footing or the beams of a gridded strip footing were not typically placed continuously across the structure in both the longitudinal and transverse directions.

Another common problem in the 1970s and early 1980s was that the reinforcement content in the footings was low, so that in many cases, the bending moment to cause a concrete flexural crack (MCR) was greater than the ultimate bending moment (MU) of the footing section.

Therefore, many cases of brittle footing failure occurred, resulting in large footing movements. The footing design procedures now require the ratio MU/MCR to be not less than 1.2 to ensure adequate ductility.

Adequate gridding, together with an increase in the reinforcement content in the footing beam to improve the footing ductility, are both aspects required in the computer footing design methods. This has greatly reduced the incidence of problem cases.

The much needed improvement in design methods can be demonstrated by Figure 1, which shows an example of a typical raft footing constructed in Adelaide in the late 1970s.

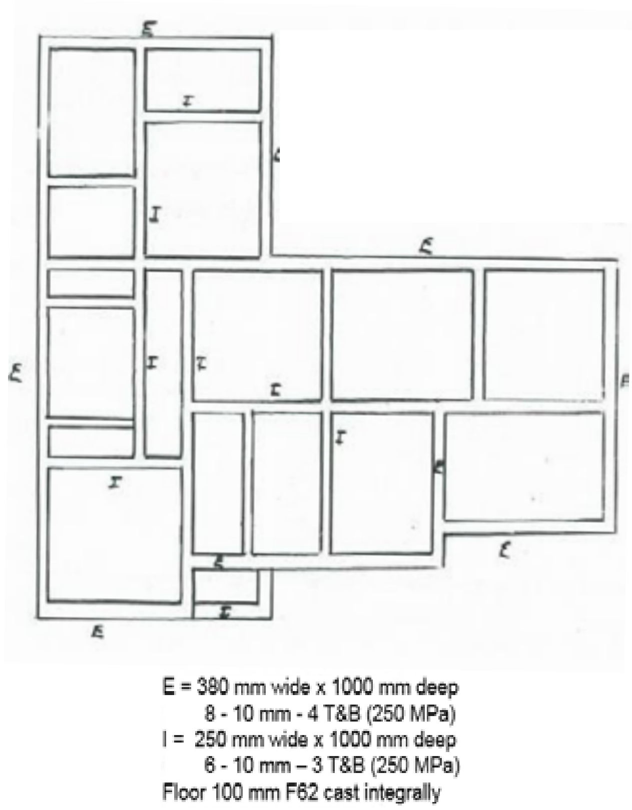


Figure 1: Raft design from late 1970s

Note in Figure 1 the lack of a suitable grid layout and the low content of reinforcement for the footing size adopted, meaning that the footings have inadequate ductility. The raft footing distorted into a centre heave mode (hogging or convex bending) as shown in a diagrammatic manner in Figure 2.

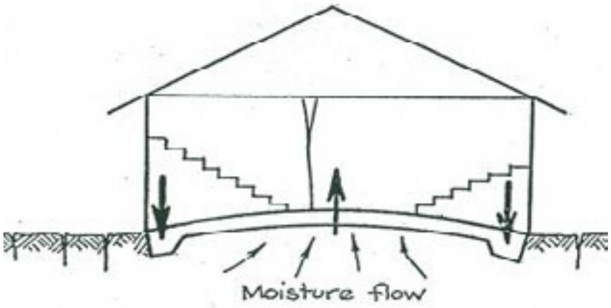


Figure 2: Centre heave mode

The lack of a suitable gridded layout and low sub-beam ductility contributed to the footing failure mechanism shown in Figure 3. A 'hinge' developed across the house whereby two sections of the structure underwent an appreciable differential distortion in a brittle failure mode.

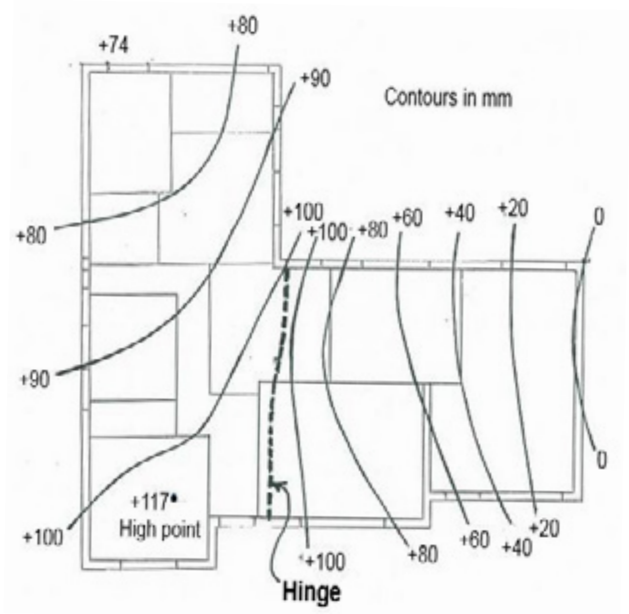
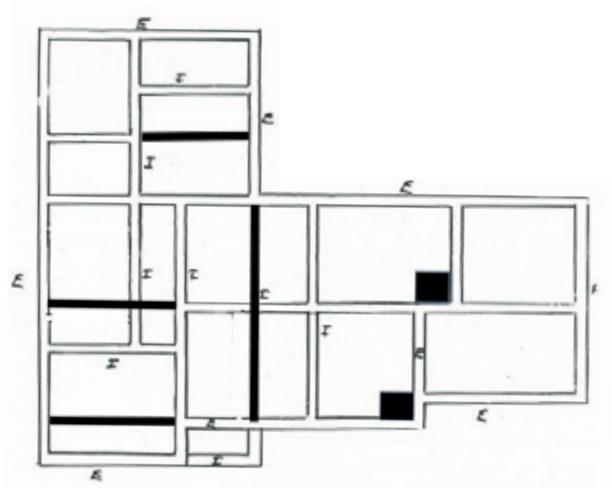


Figure 3: Distorted shape of raft

The nature of the house cracking is shown in Figures 4 and 5. This cracking is reflective of a centre heave mechanism of failure.

Fig. 4: Corner crack **Fig. 5: Ceiling crack**

Using the procedures now incorporated in the computer design procedures of AS2870, for an adequate footing, it can be shown that the same footing depth can be adopted, but with additional reinforcement to ensure ductility, and more satisfactory gridding, as shown in Figure 6.



E = 380 mm wide x 1000 mm deep
8 - 20 mm - 4 T&B (410 MPa)
I = 250 mm wide x 1000 mm deep
6 - 20 mm – 3 T&B (410 MPa)
Floor 100 mm F72 cast integrally

Figure 6: Footing of Figure 1 designed by present day methods

Improvements in the design methods have meant that if a cost-effective footing constructed on an expansive soil is subjected to the characteristic soil movement for the site, then the footing design will have a satisfactory probability of success.

Problems continue however, when abnormal soil moisture changes occur, as outlined in the following examples.

2 CRACKED HOUSE EXAMPLE No. 2

Figure 7 shows the sub-beam layout and footing details of a well-designed raft footing in Adelaide. The sub-beam gridding, footing ductility and other design details were in accordance with current acceptable practice.

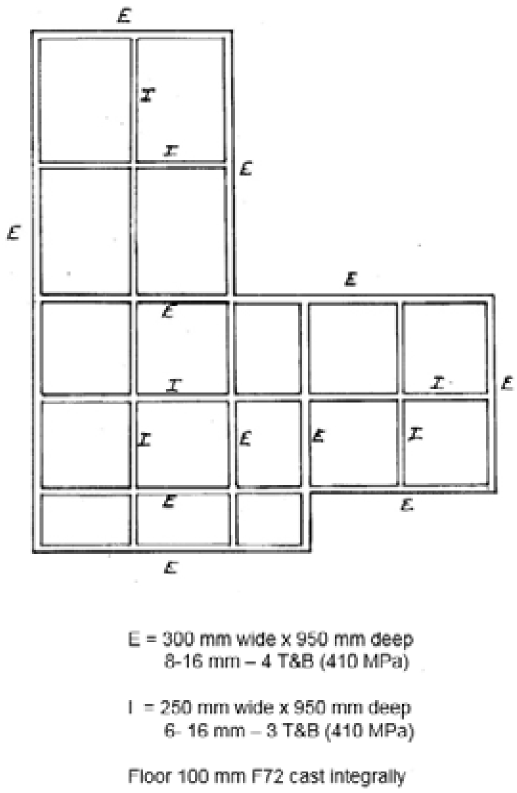


Figure 7: Example of a well-designed raft footing

Shortly after construction however, the raft footing distorted into an edge heave mode (sagging or concave bending) as shown in a diagrammatic manner in Figure 8.

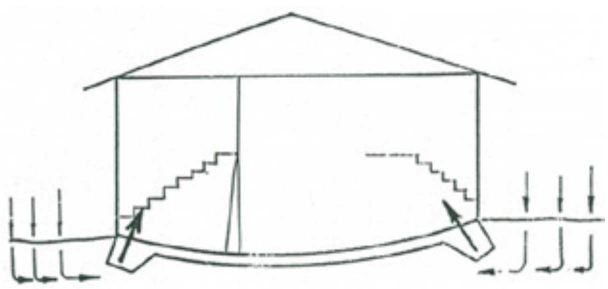


Figure 8: Edge heave mode

The distorted shape of the raft is shown in Figure 9. It can be seen that a differential movement of up to 100 mm was measured over the slab.

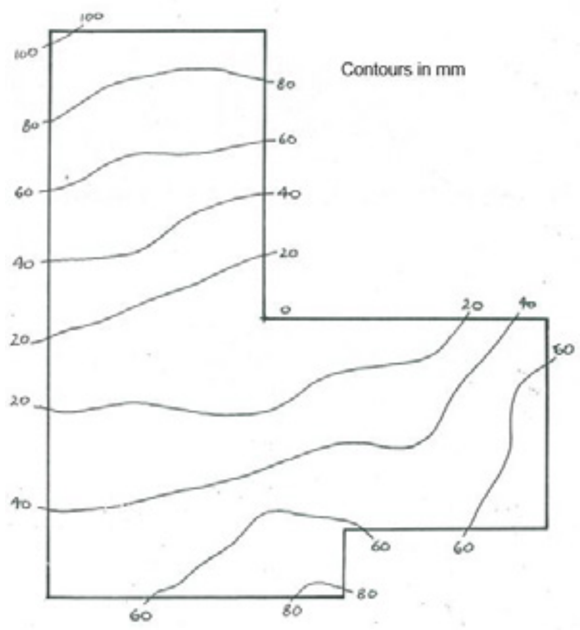


Figure 9: Distorted shape of raft

The nature of the house cracking is shown in Figures 10 and 11. This cracking is reflective of an edge heave mechanism of failure.

Figure 10: Cracking in wall

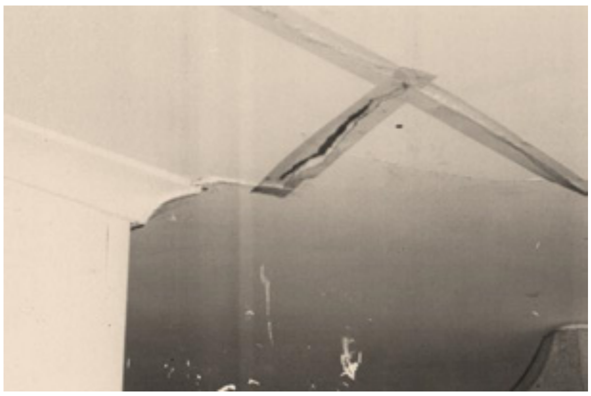


Figure 11: Ceiling crack

An investigation into the causes of the significant footing distortion, despite the footing being well designed, indicated that the site was subjected to abnormal moisture (or soil suction) changes. These abnormal soil suction changes were associated with the presence of a former house on the site, the removal of many large trees prior to the construction of the new house, and the discovery of at least six plumbing leaks, as shown in Figure 12.

These abnormal suction changes were well outside the design soil suction changes incorporated in AS2870.

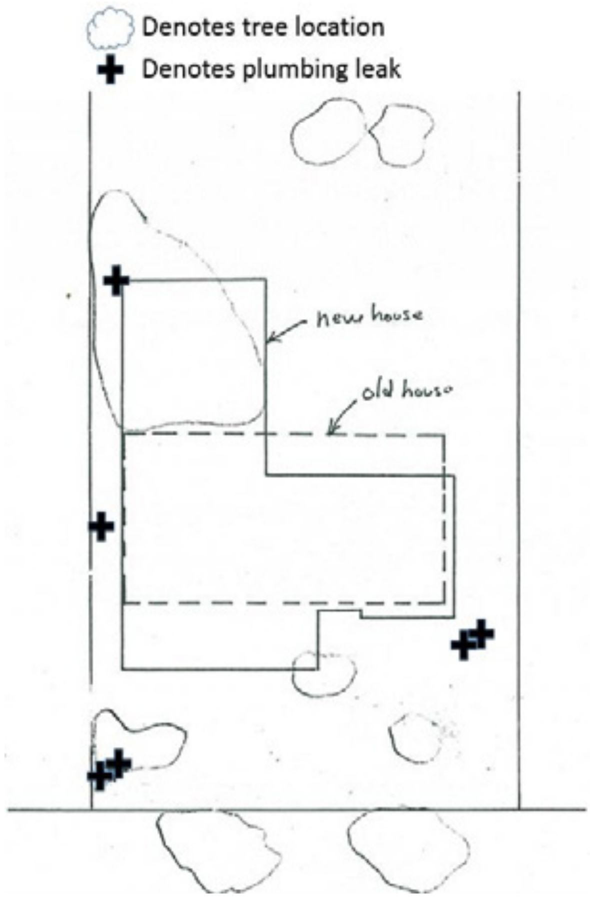


Figure 12: Location of abnormal sources of soil suction change

This case history illustrates that it is possible, given the presence of abnormal moisture changes, to significantly distort even well-designed footings. The presently used computer methods of design can predict these distortions. This case study emphasizes the importance of recognizing the effects of abnormal moisture changes described in AS2870.

3 CRACKED HOUSE EXAMPLE No. 3

One cause of an abnormal moisture change is that due to the effects of trees. Figure 13 shows typical crack patterns associated with a house deformed into convex bending by a tree which has created a differential soil settlement across the structure.

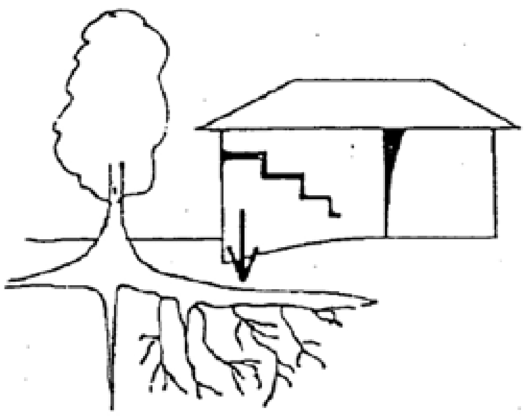


Figure 13: House distorted by the effects of a nearby tree

Figure 14 shows, for a house in Adelaide, the measured soil suction (in units of pF) due to the effects of trees. It can be seen that in the area of the house affected by the trees, the gradient of soil suction change is very high as indicated by the closely spaced soil suction contours. This means that the curvature of the settled soil surface caused by these soil suction changes is very severe.

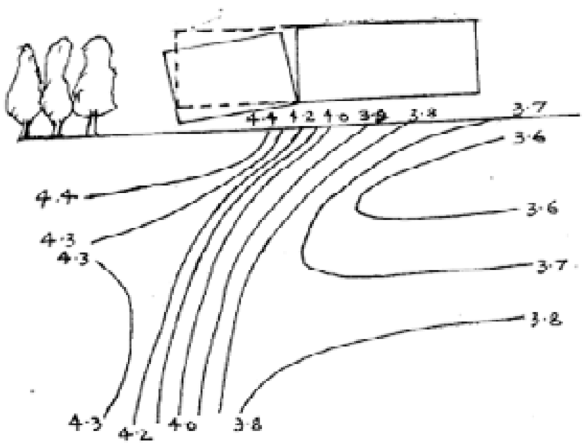


Figure 14: Measured soil suction under a house near trees

Figure 15 shows the calculated deflected shape of the soil surface due to the soil suction changes in Figure 14. The measured footing deflection is also indicated in Figure 15.

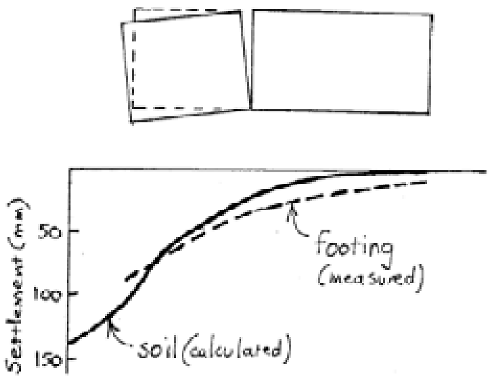


Figure 15: Calculated soil settlement profile and measured footing settlement

Computer methods, using the parameters for tree design in AS2870, can be used to design for the effects of trees, and largely, these have been successful. However, as shown in Figure 14, the pattern of soil suction change due to tree root effects can be quite complex, and the distorted shape of the footing affected by the tree can also be complicated, as shown in Figure 15. These effects may be outside the parameters incorporated in AS2870.

The prediction of the angular distortion of the footing in a zone of severe soil suction changes from tree effects must be regarded as remaining outside current knowledge.

4 CONCLUSIONS

The use of computer aided design procedures has greatly assisted in the design of footings by AS2870, so that a cost-effective footing design on expansive soils, using the procedures of AS2870, now has a high probability of success.

However, even well designed footings can suffer damage by abnormal moisture changes, particularly due to trees. Even though computer methods of footing design can be used in accordance with AS2870 to design for the effects of trees, it is emphasized that the complex pattern of soil suction changes due to trees is outside current engineering knowledge, and building owners should be warned of this.

1980-1989

An Engineering Approach to the Design of Footings on Expansive Soil

P.W. MITCHELL & D.L. AVALLE
Pak-Poy and Kneebone Pty Ltd

1. INTRODUCTION

The routine design of shallow footings of structures on expansive soil can either be based on the selection of standardised footings based on regional experience or by individual engineering design.

Standardised designs are very convenient to use, and are appropriate for large areas of uniform soil profiles and where experience has been accrued over many years. An example of this is the current use of standardised designs in Melbourne [illegible]. However, an inherent disadvantage is that they are restricted by the geographical location for which they have been developed. They can also be conservative for a particular case.

Hence, the authors [illegible] to develop techniques for footing designs for expansive soils which are based on an individual design process. However, existing techniques vary in their complexity of their representation of the soil and structure and the analysis of the interaction process, and have been found to be controversial. It must be recognised, thus, that no method, despite its complexity, could wholly anticipate conditions of the actual field situation.

In this paper [illegible] a method that the authors have successfully used for several years in the design of footings on expansive soils. The method is based on a necessary simplification of the actual soil and structure, and has been developed progressively by the first author in Adelaide (Mitchell [illegible]) and it has been used for many projects in other parts of Australia.

2.2 Loading

Complex load patterns can be simplified into edge loads (w), interior centre line loads (T) and interior uniformly distributed loads (w).

2.3 Initial Shape of Distorted Soil Surface

The free soil differential movement (Y) is defined as the differential soil movement at the perimeter of the structure with respect to the interior of the structure if the footing was unloaded and perfectly flexible. The differential soil movement is caused by suction change within the soil across the structure.

A mathematical derivation of the shape of the distorted soil surface (Mitchell 1979, 1984a) has found the shape can be approximated by [illegible] equation $y = Y(2x/L)^m$. The shape factor m is simply a function of the length (L) and the depth of soil suction change (h). For a [illegible] where there is a finite suction gradient at the surface under the structure, which is generally the case even with a concrete floored structure, then m = 1.5L/h.

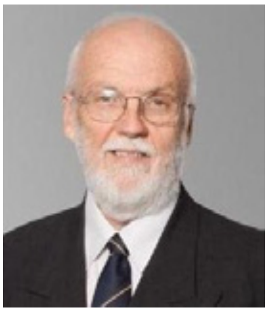
The magnitude of soil movement can be conveniently calculated for a change in soil suction Δu (pF) and soil constant I_{pt} by

$$y = \sum I_{pt} \Delta u \Delta h \qquad (1)$$

The value of I_{pt} in equation (1) can be conveniently obtained from the core-shrinkage test (Mitchell and Avalle 1984). Typical values for I_{pt} range up to 10%, depending on the reactivity of the soil sample.

Vignette from *Australian Geomechanics* June 1984

NEIL MATTES CHAIR 1988-90



In Sydney, a project of major geotechnical interest was the construction of the Sydney Harbour Tunnel, involving conventional driven and cut-and-cover tunnelling on the approaches, immersed tube installation for the harbour crossing, and construction and operation of the casting basin for the immersed tubes at Port Kembla.

My term as Chairman of the AGS spanned the years 1988-1990, following on from Dr Peter Mitchell, and later handing on to Max Ervin. 1988 was a big year for the AGS, as in May we hosted the 5th Australia New Zealand Conference on Geomechanics in Sydney, with the theme "Prediction versus Performance". The conference organising committee was led by Professor Harry Poulos, and there were more than 250 registrants. The conference was opened by Professor Bengt Broms, Chairman of the ISSMFE, and the Keynote Address on "Prediction, Design and Performance in Geotechnical Engineering" was given by Professor JM (Mike) Duncan of Virginia Polytechnic and State University.

His conclusions contained only one equation:

Failure = Litigation = Most Undesirable!

The technical program from the conference gives a good snapshot of areas of particular interest at that time:

State of the Art Talks

"Evaluation of Geotechnical Performance" (Max Ervin)

"Geotechnical Aspects of Earthquake Engineering" (Dr G R Martin)

"Prediction of Rock Excavatability" (John Braybrooke)

General Reports/Panel Review and Discussions

Groundwater problems	Ground stress and movements	Geotechnical testing
Underground mining & excavation	Geotechnics of weak/jointed rock	Shallow foundations
Mining subsidence	Open-cut mining	Earthquake & vibrations
Stability of slopes in soil & rock	Deep foundations	Failures as a yardstick for prediction ability

Membership of the AGS rose from about 580 in 1988 to over 700 in 1990. One of the key benefits of AGS membership has always been its regular publications, and comments from the editor of *Australia Geomechanics* in May 1988 provide an interesting reminder of the rapid changes then taking place in office technology: *"With the advent of word processors and floppy disks the production of technical papers is considerably more flexible, although not necessarily any quicker – unfortunately most of the word processing packages in use are essentially incompatible with the hardware and software from other manufacturers, and so the simple transfer of floppy disk contents....at this stage is not practicable. Furthermore, the practicalities of re-formatting material produced with different WP packages is akin to the problems experienced with the building of the Tower of Babel."*

In the 1980s, development of offshore infrastructure for the North-West Shelf oil and gas projects was the impetus for major studies into the behaviour of calcareous sediments, particularly in relation to the foundations for the new North Rankin A and Goodwyn A platforms. The decision by Woodside Offshore Petroleum P/L to make this experience publicly available was the catalyst for an International Conference on Calcareous Sediments in Perth in March 1988, with 38 of the 76 papers relating to the investigation, analysis, design and construction of the North Rankin A foundations. At the 5th ANZ conference Harry Poulos delivered the John Jaeger Memorial Address on the topic "Mechanics of Calcareous Sands", and in 1989 Dr Mohamed Khorshid visited all the State groups to deliver his E H Davis Lecture on "Geotechnical Aspects of the Woodside Project".

In Sydney, a project of major geotechnical interest was the construction of the Sydney Harbour Tunnel, involving conventional driven and cut-and-cover tunnelling on the approaches, immersed tube installation for the harbour crossing, and construction and operation of the casting basin for the immersed tubes at Port Kembla.

The second E H Davis Memorial Lecture "From Theory to Practice in Pile Design" was presented Australia-wide in 1988 by Professor Harry Poulos. The first D H Trollope Medal, for the best PhD thesis in engineering geology, rock mechanics, soil mechanics or foundation engineering accepted by an Australian university in the past five years, was awarded to Ian Swane in 1988 for his PhD thesis "Cyclic Behaviour of Laterally Loaded Piles". AGS members were key participants in several Australian Standards committees – updates of the piling code AS2159 (1978) and the site investigation code AS1726 (1978), and finalising the draft of the new earthworks code which was published as AS3798 in early 1991.

Personally, my employment change in this period gives an insight into broader changes taking place in the engineering profession on the late '80s. For 18 years I had worked for the Electricity Commission of NSW in its civil/geotechnical group during a period of unprecedented growth in power generation and distribution, particularly in NSW, Queensland and Victoria. The aluminium industry had been cleverly playing off the various Governments against each other to "win" proposed smelters in their State, most of which did not eventuate, with the inevitable outcome of serious over-capacity by the end of the decade, and no prospect of building any major new power stations for the foreseeable future. Consequently, I was part of a widespread exodus of professionals from the power utilities to private industry, joining Coffey Partners at the start of 1989. Historically, the vast majority of the engineering for public infrastructure projects had been carried out by governments' in-house resources, and my move from public to private sector was symptomatic of the widespread trend throughout Australia in the '80s to "de-engineer" the public infrastructure authorities (roads, electricity and water particularly), with a consequent greatly increased involvement of consulting firms in these fields.

I'll finish these recollections with an anecdote dating back to the start of the AGS in 1970. Long-time attendees of the AGS Sydney group technical meetings will know that an enduring feature has been sausage rolls/party pies/tomato sauce as part of the pre-meeting refreshments. This dates back to the earliest days of the group (and in fact to its predecessor, the Sydney Soil Mechanics Group), when the monthly meetings were held at the Civil Engineering School at Sydney University. The pre-meeting get-together took place in the Soil Mechanics laboratory, and one of the chores allocated to us young post-graduate students in Ted Davis' department was to ensure that the sausage rolls and party pies were well-heated (to 105°C?) in the soil-drying oven, and that Petri dishes of tomato sauce were strategically placed on the laboratory benches (and to clean up next morning before the undergraduates arrived).

Professor Harry Poulos of Sydney University, holding the John Jaeger Medal awarded to him at the 5th Australia-New Zealand Geomechanics Conference.

Vignette from *ISSMFE News* Vol 15, No4

AUSTRALIAN GEOMECHANICS SOCIETY

FIVE YEAR PLAN 1990-1994

DEFINITION

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 the ground, including recovery of the earth's mineral resources.

AIMS AND OBJECTIVES

The aims and objectives of the Society during the period 1990 - 1994 will be as follows:-

1. To work with its sponsoring bodies, The Institution of Engineers Australia (IEAust) and The Australasian Institute of Mining and Metallurgy (AusIMM), to create greater public awareness of the Geomechanics profession and its contribution to society.
2. To maintain and improve standards and to promote professional conduct in the practice of Geomechanics.
3. To promote (i) the evaluation and consolidation of existing knowledge and its relevance to practical geomechanics, (ii) the assessment of the reliability of various analytical and design procedures, and (iii) research and investigation into geotechnical problems which are particularly relevant to Australian conditions.
4. To increase membership of the Society and, in particular, to encourage wider participation in the Society by persons involved in the Mining, Construction and Engineering Geology sectors.
5. To increase the numbers of organisations involved in the Society as Supporting Members.
6. To promote Australian Geomechanics by hosting appropriate local and international seminars and conferences.

Vignette from *Australian Geomechanics* January 1990

GUEST EDITORIAL

By Neil Mattes,

Chairman Australian Geomechanics Society

This special edition of Australian Geomechanics marks the Fifth Australian New Zealand Conference on Geomechanics and is being issued to all participants in this most important event. The Conference is the latest in the series which started in Melbourne in 1971, followed on by a four yearly cycle in Brisbane, Wellington and Perth; but our younger members in particular may not be aware that the tradition of Australian and New Zealand Conferences goes back much further than 1971; the first Australia New Zealand Conference on Soil Mechanics and Foundation Engineering was held in 1952, and a further four conferences under that title followed. With the broadening of the scope to cover both soil and rock mechanics, the title was changed to Geomechanics, and we started numbering from one again ... this conference is really the Tenth ANZ Conference!

Organising for the conference started in 1985, and the committee, under the chairmanship of Professor Harry Poulos, is to be congratulated on putting together a program which should result in a most enjoyable and productive week for all participants. A feature of the format is the use of poster sessions for the presentation of all technical papers; while some authors may lament the opportunity to present their paper to an audience in formal session, I believe the majority will welcome the chance to discuss their contribution with participants who have a particular interest in their subject, in the relaxing atmosphere of a poster session, rather than the more usual rushed and stressful auditorium presentation. From a practical point of view, the chosen format allows for a good mix of invited keynote and state-of-the-art addresses, general review sessions with plenty of time for discussion by expert panels and the audience, and case history exercises. The number of papers and topics to be covered makes it necessary to have concurrent technical sessions, and while these have been grouped to minimise obvious overlap of interest, some participants will find they would like to be in two places at once ... we can't organize that, but at least they will have the opportunity to look at all papers and talk to their authors during the poster sessions.

Of particular significance are the Case History Sessions. Interested registrants have been sent datasets applicable to real-life situations involving geotechnical studies and analysis, and have been asked to predict various aspects of performance. Their predictions will be collated and presented by the session co-ordinators, who will then reveal the actual observed performance ... this type of exercise is the ultimate test of where our profession stands in the real world of non-ideal loadings on materials which behave naturally rather than ideally, and the results should be most interesting and entertaining!

Two important Awards will be presented during the Conference. *The John Jaeger Memorial Award* recognises and promotes contributons of the highest order in the field of Australian Geomechanics. First awarded in 1980, it perpetuates the memory of John Jaeger, who was Professor of Geophysics and Geochemistry at the Australian National University from 1953 until his death in 1979, and was a "founding father" of Australian geomechanics, particularly in relation to rock mechanics. The first Jaeger Medal was awarded to Professor Ted Davis, and the second, in 1984, to Dr Gordon Aitchison. To this most exclusive group we can now add **Harry Poulos**, Professor of Civil Engineering at the University of Sydney, who has been selected to receive the 1988 Medal. Professor Poulos needs no introduction to members of our Geomechanics Societies: his name is synonymous with pile foundations world-wide, and he has made, and is making, major contributions in many other aspects of geomechanics. I believe that Professor Poulos is representative of the "second generation" of practitioners, who learnt and developed their profession in the environment created by pioneers such as John Jaeger, Ted Davis and Gordon Aitchison.

Another major pioneer of Australian geomechanics is Professor Hugh Trollope, who in 1957 was the first recipient of a Ph.D. awarded by an Australian University in the field of geomechanics. To commemorate this event, the AGS has established the D.H. Trollope Medal, to be awarded on a two yearly cycle to the author of an outstanding doctoral thesis accepted by an Australian University during the preceding five years in the fields of engineering geology, soil mechanics, rock mechanics or foundation engineering. The first D.H. Trollope Medal will be presented during the Conference to **Dr Ian Swane**, for his thesis entitled "The Cyclic Behaviour of Laterally Loaded Piles".

On behalf of the National Committee of the Australian Geomechanics Society, it is my pleasure to welcome all participants to the Fifth ANZ Conference ... I trust your week will be both rewarding and enjoyable.

Vignette from *Australian Geomechanics* June 1988

1980–1989

SOFT ROCKS AND ROCK SOCKETED PILE RESEARCH AT MONASH UNIVERSITY

Following a PhD from the University of Southampton in 1972, Ian Johnston has worked on geotechnical projects in many countries, held senior academic appointments including at Monash University and the University of Melbourne, and been active on several professional and governmental boards.

He presented the E.H. Davis Memorial Lecture in 1991, received the John Jaeger Memorial Award in 2012 and was appointed an Officer of the Order of Australia (AO) in 2017.

PROFESSOR IAN JOHNSTON AO

The Silurian and Lower Devonian formation, commonly referred to as the Melbourne Mudstone, is a dominant feature of the geology of Melbourne and provides the founding stratum for a significant proportion of the city's larger structures. For many years, foundations, in the form of bored piles drilled or excavated into the mudstone and often referred to as rock-socketed piles, were designed and constructed using practices which were acknowledged as being conservative. The first significant steps towards more rational design were made by Dick Parry (who later went on to become the Secretary-General of ISSMFE) for the King's Bridge over the Yarra which was opened to traffic in 1961. Based on triaxial tests, it was established that there was a strong correlation between measured water content of the mudstone and both its strength and modulus. This was used to determine founding levels for the piles to satisfy the stringent performance specifications laid down by the Country Roads Board (CRB, now VicRoads).

A few years later, the Johnson Street Bridge was constructed. Alan Parkin and Ian Donald extended the principles developed with the King's Bridge with base and side resistance of the piles acting together. Using the results from a program of laboratory tests, designs based on soil mechanics practice were proposed. It was made clear, however, that significantly greater base and side resistances in the mudstone were likely but field tests would need to be conducted to justify these increases.

Around the mid-'70s, the CRB was giving careful consideration to the design of piles which would be required to support the elevated portions of the Westgate Freeway. Piles socketed into the underlying mudstone were the most likely solution, but it was recognized that significant savings on pile costs were possible if the designs were based on the superior qualities of the mudstone. Adrian Williams (PhD, 1980) was seconded from the CRB to develop a rational approach to rock-socketed pile design.

At about the same time, Ian Johnston had recently joined Monash as a new lecturer and with Ian Donald, Adrian, support from the CRB and other projects, commenced the first significant phase of the research project. Soon after this, Chiu Hong Keong (PhD, 1981) joined the group.

For the next 4 to 5 years, the team worked on three major integrated areas; field testing, laboratory testing and numerical modelling. The field testing component involved a range of pile tests aimed at characterising end bearing and side shear resistance, acting separately and together, in instrumented piles for diameters up to about 1.6m. Various sites were selected to provide different rock strengths. Geometry, including different pile length to diameter ratios and socket wall roughness, were also investigated, as well as a few tests specifically directed at examining construction practice. Figure 1 shows two of these latter piles after excavation for the inspection of defects.

Figure 1: Piles excavated to examine construction defects

A novel technique for field testing was developed initially for the Melbourne Underground Rail Loop Authority (MURLA) for the elevated rail section between Flinders Street and Spencer Street Stations. This involved the simultaneous testing of both end bearing and side resistance components of a pile socket through the use of flat jacks placed between the two components, with the pile socket being completed as a functional pile after testing. Figure 2 shows the prototype test rig about to be lowered into a 1.2m diameter socket.

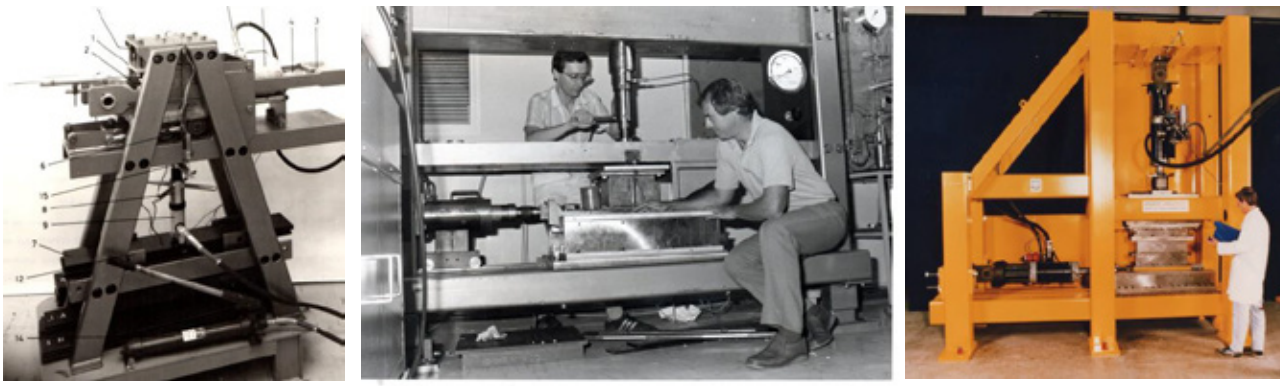
The team has occasionally regretted not patenting this approach to pile testing!

Figure 2: MURLA test rig for simultaneous base and side testing being lowered into a socket

The laboratory testing component comprised two related programs. One was essentially testing for engineering properties (principally strength and modulus) with triaxial techniques that were relevant to a material which was stronger, more brittle and less compressible than traditional soils. It was shown that with the appropriate specimen geometry, confining pressures, rates of load application and consideration of failure mechanisms, meaningful properties could be derived. It was also demonstrated that although the mudstone has a relatively low permeability, drained parameters were relevant to design in these materials.

The second component of laboratory testing involved the development of the constant normal stiffness (CNS) direct shear test. This laboratory test duplicated the stress conditions that developed on the interface between the pile shaft and the side of a socket. Because of the roughness of this interface, and the relative strengths of the concrete and rock, the socket dilated horizontally on the interface asperities as the pile deflected vertically. This gave rise to an increase in the normal stress acting on the interface to cause a significant increase in the shear resistance along the side of the pile. The side shear resistance was, therefore, a complex combination of sliding, dilation, and progressive shearing against the constant normal stiffness of the rock mass. All of this could be modelled using a CNS direct shear machine. The first CNS machine (Figure 3a) was used to examine the effects of several factors including roughness and normal stiffness. While the agreement with the field test data was very encouraging, it was clear that this first CNS machine needed to be more robust to fully model this process.

The numerical modelling component was based on the FE analysis of general axisymmetric problems developed by Scott Sloan (MEngSc, 1978). Chiu developed this program further to provide further insight into the development of both end and side resistances.



(a) (b) (c)

Figure 3: Three generations of CNS direct shear machines

By the early '80s, one of the outcomes of this first major phase of research was a design method (and subsequently a program called *SOCKET*). The method and the extensive data used in its formulation also provided the basis for several other individuals around the world to develop variations of methods of design. Another major outcome of this first phase of research was the emergence of soft rock technology which over the next few years, demonstrated that the separate geotechnical disciplines of soil and rock engineering are part of the same continuous spectrum controlled by the same physical principles. Following this first phase of research, it was clear that considerably more effort was required to resolve many of the issues which had been raised.

Concentrating on base resistance, Xavier Choi (PhD, 1984) commenced work examining the mechanisms involved so that numerical models could be constructed to reproduce the processes. It was recognized early on that test results could be significantly influenced by inherent variations in the properties of the natural mudstone to the extent that it was difficult to identify key factors. To overcome this problem, a synthetic mudstone was developed made from ground mudstone and a little cement, water and calcium chloride. The key to reproducing the critical characteristics of natural soft rock (in particular a stress history, dilatant characteristics and a low porosity which is not achieved when using a material such as plaster), was that the above mixture was compressed in molds under pressures of up to 40MPa prior to allowing the specimens to cure. In this way, synthetic mudstone specimens of up to 300mm height and diameter could be produced to replicate highly and moderately weathered natural mudstone but with homogeneous and isotropic properties. Thanks to Ian Donald's quirky sense of humour, this material became known as *Johnstone*. Xavier demonstrated that tensile strength was a major factor in the development of base failure (Figure 4) and numerical modelling showed that the ultimate base resistance of a rock-socketed pile could be about eight times the uniaxial compressive strength (UCS) for L/D =0 increasing to about sixteen times UCS for L/D >5.

Because of the dilatant and relatively brittle characteristics of soft rock, it was clear that tensile strength was an important parameter controlling loading performance. Although some work was undertaken in the intervening period, Wilson Lim (PhD, 1992) studied tensile failure related mixed-mode fracture propagation in soft rock using finite element methods and experimental techniques. The modelling techniques developed were able to predict fracture trajectories as well as acceptable load-displacement curves to support the general conclusions reached earlier.

After 1980, the side resistance component also required more work to better understand the shear behaviour of the rough concrete-rock joints forming the interface between the pile and the rock. Thomas Lam (PhD, 1984) developed a more robust CNS direct shear machine (Figure 3b, although this shows Elio Novello and Ian Johnston working on this machine conducting commercial tests). A large suite of tests were conducted on concrete-rock interfaces formed with regular triangular asperities, regular sinusoidal asperities and finally irregular asperities. The data from these tests was used to develop a mathematical model to predict the side resistance of a socketed pile.

This was followed by a number of research projects related to the side resistance. Melvyn Tan (MEngSc, 1987), developed design charts for predicting socket side shear on the basis of characteristic τ-z curves. Jayantha Kodikara (PhD, 1989) extended our understanding of the side resistance through tests on irregular triangular concrete-rock joints under CNS conditions. Mak Ran Haw (PhD, 1992), looked at the post-peak behaviour of concrete-rock interfaces using a specially designed and constructed rotary CNS shear machine which could test specimens to large shear displacements.

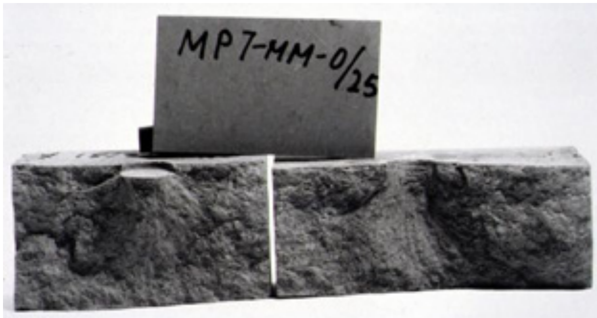


Figure. 4: Failure mechanism of a model pile base

While there was ongoing work on the properties of soft rock in the laboratory, it was also known that larger in-situ tests may also provide useful information about material mass characteristics. This led to the pressuremeter being considered as a viable test procedure, particularly for estimating mass modulus.

Jayantha Ameratunga (PhD, 1986) developed a numerical model to examine the many assumptions used to analyse pressuremeter test results. Amongst other factors, Jay showed that drained properties were the most relevant and proposed a method for deriving drained cohesion and friction. He was followed by Chris Haberfield (PhD, 1987) who showed that the expansion of a pressuremeter was most likely to cause radial cracking in the rock mass. A unique feature of the experimental work was a series of small scale pressuremeter tests conducted in a triaxial cell which allowed the calibration of a numerical model. Figure 5 shows two of the *Johnstone* test specimens used for these tests. The numerical model led to a new method of interpreting pressuremeter test results for modulus and drained strength parameters.

Figure 5: Test specimens for small scale pressuremeter tests in a triaxial cell

Following up on the concept of a continuous geotechnical spectrum, Elio Novello (PhD, 1988) undertook a large number of carefully monitored triaxial tests on *Johnstone* specimens, which through the critical state framework, provided further support to the general philosophy that soils and rocks are different by definition and degree rather than of kind. The data sets used in the overall analyses were extended to include calcarenite which was extensively tested at Monash using both high pressure triaxial and CNS equipment as part of the North Rankin A offshore oil platform foundation modifications. Further support for the concept of a continuous spectrum of materials for all soils and rocks was provided by the development of a strength criterion for all intact geomechanical materials. This was based on over 1700 individual test results from about 100 different sources around the world. The criterion applies to normally consolidated clays, over-consolidated clays, soft rocks through to hard rocks for both compressive and tensile stress regions. The criterion also explains why the ratio of the unconfined compressive strength to the point load index is around 25 for hard rocks but significantly less for soft rocks.

During this period, Heather Wardlaw (MEngSc, 1992) developed techniques for preparing jointed synthetic rock test specimens for triaxial testing.

While the CNS shear machine shown in Figure 3b provided great service to the understanding of side resistance, it was limited to relatively small shear displacements and essentially monotonic loading. Because of the need to extend our understanding beyond these limitations, a larger, even more robust CNS machine, capable of applying cyclic loads, was developed (Figure 3c). Julian Seidel (PhD, 1993) conducted an extensive program of tests with this machine on synthetic mudstone and on highly degradable materials similar to those encountered with the North Rankin A project. He was able to refine the models produced previously and extend them to include cyclic loading. A major end product of this work was the program *ROCKET* which predicted the performance of piles socketed into degrading and non-degrading materials.

In 1993, with Ian Johnston leaving Monash, Chris Haberfield, who had stayed on as an academic staff member, took over the reins of the rock socketed pile project. Julian Seidel joined Chris in 1994, and the two of them continued with investigations into construction effects such as the impact of drilling fluids and roughness with Felix Cheng (PhD, 1997) and Ben Collingwood (PhD, 2000); the measurement and impact of socket roughness with Ben Collingwood (see Figure 6); use of expansive cement additives to improve pile and anchor performance with Tim Chamberlain (MEngSc, 1993), Serhat Baycan (PhD, 1996) and David Jarred (MEngSc, 1997); and concrete-rock interface performance in harder rocks including sandstone and basalt with Xue Fan Gu (PhD, 2001). Serhat Baycan also undertook extensive field testing of socketed piles and anchors in siltstone (Figure 7). The fundamental concrete-rock interface research was also extended into rock-rock joints by Helen Pearce (PhD, 2001).

Figure 6: Down hole socket side roughness profiling device

Figure 7: Static load test of socketed pile at Scoresby test site

International Conference on Structural Foundations on Rock / Sydney / 7-9 May 1980

The design of socketed piles in weak rock

A.F. WILLIAMS, I.W. JOHNSTON & I.B. DONALD
Monash University, Melbourne, Australia

1 NOTATION

- A_b area of socket base
- A_s area of socket side
- c_u undrained cohesion
- c' drained cohesion
- D pile diameter
- E_c Young's modulus of concrete pile
- E_i Young's modulus of intact rock
- E_m Young's modulus of the rock mass
- F_c factor of safety with respect to capacity
- F_ρ factor of safety with respect to settlement
- f_b mobilized base resistance
- f_{be} fictitious elastic base resistance
- f_{bp} non-linear (plastic) component of base resistance
- f_{by} base resistance at yield
- f_{b1} base resistance at ρ/D = 1%
- f_s mobilised side resistance
- f_{se} fictitious elastic side resistance
- f_{sp} non-linear (plastic) component of side resistance
- f_{su} peak side resistance
- I_ρ settlement influence factor
- J_f joint frequency
- j mass factor = E_m/E_i
- L socket length
- N_c bearing capacity factor
- N_ρ bearing capacity factor with respect to settlement
- Q allowable pile load
- Q_b allowable base load
- Q_{be} fictitious elastic base load
- Q_d design load
- Q_e fictitious elastic pile load
- Q_s allowable side load
- Q_{se} fictitious elastic side load
- q_u unconfined compressive strength of rock
- S_h standard deviation of asperity height above the root line of the asperities
- S_i standard deviation of asperity angle with respect to the root line
- w moisture content
- α side resistance reduction factor reflecting rock strength f_{su}/q_u
- α_c side resistance reduction factor reflecting rock strength f_{su}/c_u
- β side resistance factor reflecting changes in rock mass modulus $= \frac{f_{su}}{\alpha q_u}$
- μ_o embedment factor
- ν_m Poisson's ratio of a rock mass
- ρ settlement
- ρ_m maximum allowable settlement
- ϕ_u undrained friction angle
- ϕ' drained friction angle
- ω reduction factor to allow for jointing.

2 INTRODUCTION

Large diameter bored concrete piles carrying heavy loads, and socketed into a rock

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The early work on the strength of rock masses was continued by Jerry Szymakowski (PhD, 2003) through the development of equipment to manufacture and test in direct shear relatively large fractured rock masses. This was extended into the performance of laterally loaded piles in fractured rock by Bernie Francis (MEngSc, 2003). Theoretical studies of rock mass strength using discrete element techniques were also undertaken by Jerry Szymakowski and of well bore stability in weak rock by Xi Chen (PhD, 1999).

Soon after 2001, with both Chris Haberfield and Julian Seidel moving to industry, the soft rock/rock socketed pile project effectively came to a close. Its 25 plus years has involved 5 academic staff, many technical staff (of which Chris Powell should receive special mention for significant input over all of these years), 18 PhD and 6 MEngSc students. It saw the development of a range of specialist testing equipment and techniques, created several hundred technical papers and presentations, received numerous awards and fostered extensive involvement with industry. It was a project which made a large impact on the practice of a specialist area of geomechanics in both Australia and overseas and demonstrated how soft rocks link the behaviour of soils and hard rocks with characteristics which were previously treated as separate technologies. It has been a privilege to be associated with it.

NEWCASTLE CHAPTER

The Newcastle Chapter of the AGS started out as an interest group extending from the Sydney Chapter; however, Newcastle's roots in the geotechnical profession go back well before the Newcastle AGS chapter was formally ratified.

Prior to 1970 consulting geotechnical services were largely provided by consulting companies based in Sydney or elsewhere. For instance, the geotechnical investigation for the Eastern Nitrogen (now Incetec) development on Kooragang Island was carried out by Coffey & Hollingsworth (Coffey) during the mid-1960s using the recently imported high capacity mechanical Dutch Cone. In 1968 Coffey was retained by the DMR to provide geotechnical services for the construction of the embankments for the Five Island Road Project. Due to the increased demand, in 1971 Coffey established an office at Wickham then Maryville in Newcastle under the management of Geoff Padgett, and the technical support of Sydney based engineers and later locally by George Black, John Harvey (1983-88) and Arthur Love.

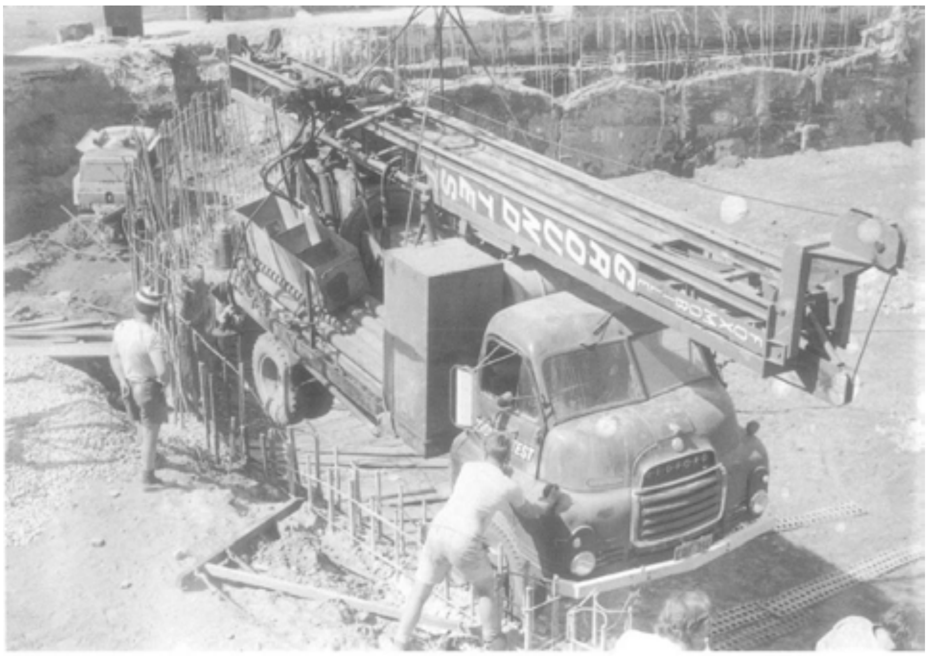
In 1954 Frankipile Aust started geotechnical drilling with the first full time staff in 1960 being Don Douglas. One of Don's earliest reports was on the site investigation for the first Tourle St bridge in 1961, carried out for BHP. That steel bridge was built in the early 1960s and demolished in 2015. Ground Test Aust started trading in 1963 as a consulting arm of Frankipile and conducted many of the major investigations in the Newcastle area including the Kurri Kurri Aluminium Smelter and the Tomago Aluminium Smelter.

In 1980 Ground Test started a small office and laboratory in Newcastle under Gerry Eastwood.

After the management/staff purchase of Ground Test by D J Douglas and Partners (Douglas) in 1983 they opened an office in National Park Street. Stephen Jones, Robert "Bob" Carr and John Harvey were prominent engineers at Douglas, initiating a healthy professional rivalry which has persisted to the present day. For many years, "Coffeys" and "Douglas" were the geotechnical consulting presence in Newcastle.

The UK based consultant, Soil Mechanics Ltd/ Ercon, had an office in Newcastle from the 1960s, set up after consulting to Hunter Water on the sealing works at Seaham Weir on the Williams River. They continued to provide consulting services to Hunter Water on rutile and zircon mining in the Tomago Sandbeds and its effect on the aquifer. Other significant investigation projects included the Carnley Avenue landslide in 1974 and the Hume Highway Goulburn By-pass in 1983. Their Australian operation was acquired by Douglas in 1983.

Between them, Coffeys and Douglas laid the foundations for the regional and industrial growth in the Hunter in the late 20th Century, for a range of projects including various parts of the BHP Steelworks, the Newcastle Harbour deepening project of the 1970s, the Tomago Aluminium smelter, the Kooragang and Port Waratah Coal Terminals, the John Hunter Hospital, the Newcastle Police Station and the Tax Office.



Ground Test drilling rig being lowered into the excavation at the Newcastle City Council 'Roundhouse' Building in 1972

In an operating environment very different to today, the other big contributor to geotechnical engineering in the region was the Department of Main Roads (DMR), and then RTA (now RMS), which prided itself on having the necessary expertise to provide all of its own necessary geotechnical design input. Supported by their own drilling rigs, and with perhaps the biggest testing laboratory in the Hunter in their Darby Street District Office, the DMR geotechnical team was led by John Randle, with support from Chris Francis, Colin Cresdee, Steve Summerelt, Chris Rodgers and Geoff Russell. The DMR constructed Stockton Bridge over the Hunter River, which was completed in 1971. At that time, it was the largest bridge constructed by the DMR.

Significant ground improvement projects undertaken in Newcastle in the 1980s included grouting of old mine workings beneath the ATO building, the first of its kind in the region, together with vibro-flotation works at the sites of the NSW Government Office building (Bull Street), the Travelodge motel building (King Street) and the grain silos in Carrington.

Coinciding with the establishment of Coffeys and Douglas in the Hunter was the establishment of a geotechnical group in the Department of Civil Engineering at the University of Newcastle. Whilst Konrad Moelle had been the foundation engineering geologist at the University, the geotechnical interest in Civil Engineering was supported on a part-time basis in the 1970s by Bob Wilson and in the 1970s and 1980s by Brian Heaton, who maintained a research interest in pavements and pavement materials. The first full-time geotechnical academic was John Berrill in 1975, followed a few years later by John Small. Thus began a grand succession of bright young graduates of Australia's eminent universities who had gone on to bigger and better things to do PhDs in some of the finest universities in the world such as Oxford, Cambridge and Imperial College. John was succeeded by Scott Sloan and Ian Moore in the early 1980s. At the departure of Ian, Scott, in a stroke of strategic prowess, managed to see Ian replaced with not one but two fine young geotechnical researchers, in Hai-Sui Yu and David W Smith. And at the retirement of Brian Heaton, his position was consolidated in geomechanics by the appointment of Mark Allman. This set the scene for things to come, with the group growing steadily to peak with the Centre of Excellence for Geotechnical Science and Engineering.

The problem of reactive soils had long been underappreciated in the Newcastle region, largely because it was difficult to identify in the predominance of flexible weatherboard structures, and because it "hid" amongst a myriad of other ground movement phenomena including mine subsidence. The NSW Mine Subsidence Board (now Subsidence Advisory NSW) undertook to resolve some of the uncertainty between mine subsidence and reactive clay movements. In 1993 it sponsored the "Maryland Project" conducted through the University of Newcastle, which was to run for the next 7 years and generate a series of landmark papers on moisture changes and foundation movements in reactive soils.

The first signs of wider competition in the geotechnical consulting environment came in 1995 with the establishment of Robert Carr and Associates, formed from Bob Carr, Phil Hitchcock, and James Young from Douglas, with Mark Delaney from Coffeys. Joined by Mark Allman in 2000, RCA Australia went on to be a core part of Newcastle's geotechnical presence, and the first truly Novocastrian geotechnical consultancy.

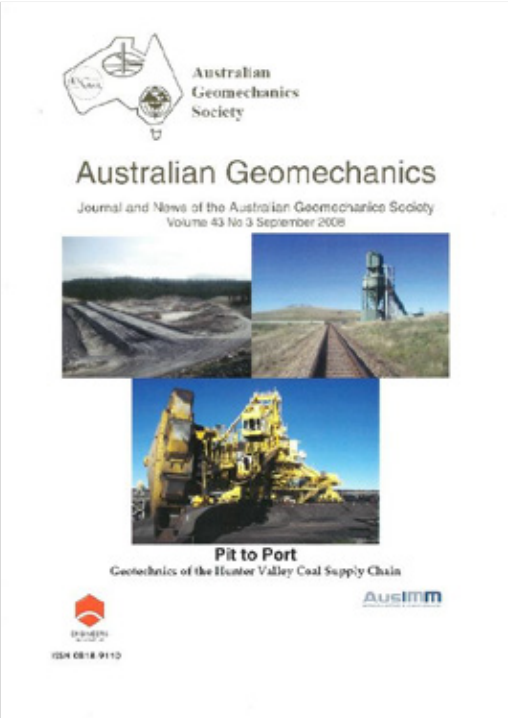
Perhaps the most significant geotechnical event in the history of Newcastle Chapter geotechnics was the 1989 Newcastle Earthquake. The magnitude 5.7 event itself had only limited geotechnical significance, but its aftermath was significant. As might be expected, the demand for geotechnical services in rebuilding the devastated city was unprecedented. But more than this, the earthquake drew renewed attention to the condition and performance of local structures, many of which mysteriously suffered recurring damage in the 6 to 12 months following the earthquake and after the initial damage had been repaired. If the importance of the region's reactive clay soil conditions had not been highlighted by its complication of mine subsidence phenomena, it certainly came to attention in the aftermath of the earthquake.

With professional interest and activity growing rapidly in both University and consulting, Newcastle began organising technical presentations, loosely as an outreach of the Sydney Chapter. With its core of geotech academics, the University was in some respects "neutral ground" and it became the default venue for both technical presentations and local committee meetings. In 1995, Newcastle had sufficiently come of age to host its own local Geotechnical Engineering conference, "Geotechnical Engineering of the Newcastle Region", the proceedings of which were published in a volume with bright orange covers. This publication went on to become colloquially referred to as the "orange book". The Chapter followed up on the success of the 1995 event by hosting a second equally successful conference on The Engineering Geology and Geotechnical Engineering of the Hunter Valley; published in a volume with bright blue covers, it became known as the "blue book".

Throughout the early 2000s, Newcastle and the Hunter Valley were regions of strong economic and industrial growth, despite closure of the BHP steel works at the start of the millennium. This attracted a new wave of geotechnical consultants, both big and small, seeing the establishment of local offices of 5QS, SMEC, GHD-Longmac, and PPK (now WSP). Cardno and Golder Associates would follow.

But Newcastle was not yet formally a chapter in its own right, and in 2002 it petitioned the then national chair, Andrew Leventhal, for status as an autonomous chapter. Andrew and the national committee were reluctant at first, but the consistent energy and enthusiasm of the Newcastle group won them over, and autonomy was granted in 2003, with Chris Bozinovski assuming the role of first "official" Newcastle Chapter Chair.

In 2008, the Newcastle AGS chapter held its Pit to Port Symposium, focused on the geotechnical issues related to the Hunter Valley coal chain.



In 2010, the chapter supported the Geotechnical group at UoN to host the 4th Asia-Pacific Conference of Unsaturated Soils under the primary coordination of Olivier Buzzi, Daichao Sheng and Stephen Fityus.

The Newcastle chapter truly took its place amongst the AGS chapters in 2012 when Sam Mackenzie became the first Newcastle chapter member to assume the role of National Chair. He was to be succeeded in 2018 by the second Chair from the Newcastle chapter, Stephen Fityus.

Geotechnical engineering in Newcastle and the Hunter Valley boasts a long history of interesting and in some instances novel solutions to unique problems. Examples include:

- Construction of the more than 40m deep slurry cut-off wall in fluvial deposits to prevent migration of contaminants from the old BHP steelworks;
- Construction of the West Charlestown Bypass and the Hunter Expressway (M15 Motorway) from zoned embankments of reactive claystones and coal and through ground with shallow and medium mine workings at multiple levels;
- Ground-freezing in deep saturated sands to construct the 14m deep casting pit at Tomago Aluminium;
- Piled embankments across soft soils at Five Islands;
- Compacted 'bottom ash' embankments carrying the Pacific (M1) Motorway across soft soils in the upper reaches of the Hexham Wetlands at Lenaghans Drive; and
- Ground improvement works to construct the biggest single coal export facility in the world on the very soft estuarine soils of Kooragang Island.

Effects of mine subsidence in an underlying seam, evident in an overlying seam exposed during construction of the West Charlestown Bypass in 2000

Arthur Love explaining the principle of a piled embankment to engineering students from the University of Newcastle at Five Islands in 2005

Long reach excavator constructing the upper part of the slurry cut-off wall to depths of up to 49m at the former BHP steel site, during an AGS Newcastle Chapter excursion in 2003

This article was prepared by Stephen Fityus and Arthur Love

NEWCASTLE CHAPTER COMMITTEES

Year	Chairman	Secretary	Treasurer	National Representative
1980				Mr D Inkson
1981	Dr John Small	Mr John Harvey		Dr John Small
1982	Dr J Small/Mr J Harvey	Mr J Harvey/Mr John Wilson		Dr John Small
1983-85	Mr John Harvey	Mr Jeff Gleeson		Mr John Harvey
1986	Dr Ian Moore	Mr Jeff Gleeson		Dr Ian Moore
1988	Mr Robert Carr	Mr Jeff Gleeson		Mr Robert Carr
1989	Mr Robert Carr	Mr Jeff Gleeson		Mr Robert Carr
1990	Mr Robert Carr	Mr Jeff Gleeson		Mr Robert Carr
1991	Records for the period 1991-1995 are incomplete. The executive and committee comprised Mr Phillip Hitchcock, Mr Stephen Jones, Mr Arthur Love, Mr John Harvey, Dr Mark Allman, Mr Bruce Grayson, Ms. Annette Woods, Mr Stephen Fityus, Dr Scott Sloan, Mr Steve Morton			
1992				
1993				
1994	Dr Scott Sloan			Dr Scott Sloan
1995	Mr Phillip Hitchcock	Mr Phillip Hitchcock		Mr Phillip Hitchcock
1996	Mr Mark Delaney	Mr Stephen Fityus	Mr Phillip Hitchcock	
1997	Mr Stephen Fityus	Mr Richard Merifield	Mr Bruce Grayson	
1998	Mr Stephen Fityus	Mr Richard Merifield	Mr Mark Delaney	
1999	Dr Mark Allman	Mr Richard Merifield	Mr Phillip Hitchcock	
2000	Dr Mark Allman	Mr Richard Merifield	Mr Phillip Hitchcock	
2001	Mr Richard Merifield	Mr Chris Bozinovski	Mr Phillip Hitchcock	Dr David W Smith
2002	Mr Richard Merifield	Mr Chris Bozinovski	Mr Phillip Hitchcock	Mr Chris Bozinovski
2003	Mr R Merifield/Mr A Love	Mr Chris Bozinovski	Dr Daichao Sheng	Mr Chris Bozinovski
2004-05	Mr Arthur Love	Mr Chris Bozinovski	Mr Stephen Fityus	Mr Chris Bozinovski
2006	Mr Chris Bozinovski	Mr R Kingsland/Mr S McKenzie	Dr Jie Li	Dr Stephen Fityus
2007	Mr Chris Bozinovski	Mr R Kingsland/Mr S McKenzie	Dr Jie Li	Dr Stephen Fityus
2008	Dr Stephen Fityus	Mr Robert Kingsland	Mr Jason Lee	Mr Sam McKenzie
2009	Dr Stephen Fityus	Mr Robert Kingsland	Mr Jason Lee	Mr Sam McKenzie
2010	Mr Jason Lee	Mr David Knott	Mr Shannon Kelly	Mr Peter Fennell
2011	Mr Jason Lee	Mr David Knott	Mr Shannon Kelly	Mr Peter Fennell
2012	Mr Peter Fennell	Mr David Knott	Mr Shannon Kelly	Mr Peter Fennell
2013	Mr Peter Fennell	Mr David Knott	Mr Shannon Kelly	Mr Peter Fennell
2014	Dr Jim Hambleton	Dr George Kouretzis	Dr Michele Spadari	Dr Stephen Fityus
2015	Dr Jim Hambleton	Dr George Kouretzis	Dr Michele Spadari	Dr Stephen Fityus
2016	Mr Mason Crumpton	Mr John Johnston	Dr Glen Burton	Mr Mason Crumpton
2017	Mr Mason Crumpton	Mr John Johnston	Dr Glen Burton	Mr Mason Crumpton
2018	Dr Glen Burton	Mr Daniel Barnes	Mr John Johnston	Dr Glen Burton
2019	Dr G Burton/Mr P Fennell	Mr Adin Uhrig	Mr John Johnston	Mr Peter Fennell

NEW SOUTH WALES CHAPTER

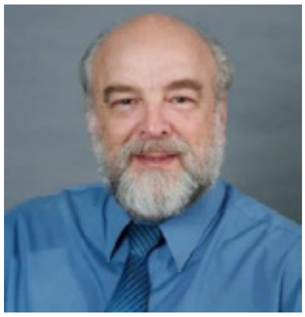
The inaugural meeting of the Sydney Group of the Australian National Society of Soil Mechanics and Foundation Engineering first met on Thursday, August 13, 1964, at 5.45 pm. At this meeting, some notable members of the Sydney geotechnical community were nominated as office bearers, including E.H. Davis, D.D. Coffey, D.J. Douglas, C.R. Longworth, and I.G. Bowie. This society also provided the foundation for the Australian Geomechanics Society (AGS) as we know it today, which was formed in 1970 and will therefore be celebrating its 50th anniversary in 2020.

Dr Harry Poulos

Since that time, many members of the Sydney Chapter have taken a leading role in the Australian geotechnical industry, including Dr Harry Poulos, who served continuously on the Sydney Chapter committee from 1974 to 2001, and whose pivotal work on pile behavior and design has been internationally recognized for more than 40 years.

Book No. 3 by Poulos and Davis, in *Series in Soil Engineering*, edited by T. W. Lambe and Robert V. Whitman, published 1974

Another leading figure in the Sydney geotechnical community is Mr Andrew Leventhal who was recently recognised for his considerable contributions to geotechnical engineering and the wider community (such as his work on Landslide Risk Management in Australia, his time as Chair of the Sydney division of Engineers Australia, and as National Chair of the AGS) with the award of Member (AM) of the Order of Australia. It is interesting to note that other AM recipients in the Sydney Chapter include Professor Harry Poulos and Professor John Carter.



Mr Andrew Leventhal

Nationally, the number of contributions made by Australians in pioneering and advancing pile foundations, mining and rock mechanics, offshore geotechnology, computational geomechanics, ground improvement, railway geotechnology and environmental geotechnics is astounding in proportion to the size of the AGS. Contributions made by members of the Sydney Chapter to the practice on a national (and international) level include:

- Pells, P. J. N., Douglas, D. J., Rodway, B., Thorne, C. P., and McMahon, B. R. (1978) *Design loadings for Shales and Sandstones in the Sydney Region*, published in the Australian Geomechanics Journal. This landmark paper provided a classification system for the Sydney shales and sandstones which was adopted throughout the Sydney Basin, and which has influenced geotechnical engineering practice within sedimentary sequences throughout Australia. It also had its roots in a course run by the Sydney Chapter and Engineers Australia in 1977.

Dr Philip Pells

- Walker, B., Dale, M., Fell, R. M., Jeffery, R., Leventhal, A. R., McMahon, M., Mostyn, G., and Phillips, A. (1985) *Geotechnical Risk Associated with Hillside Development*, which was published in Australian Geomechanics, and the Sydney Morning Herald and also presented at a Local Government Engineers Conference. This document pushed the industry away from the use of the term "stable" in landslide risk assessments, and laid the groundwork for the nationally applied Practice Note Guidelines for Landslide Risk Management, 2007, that included the "Good" and "Poor" Hillside Construction Practice example cartoons.

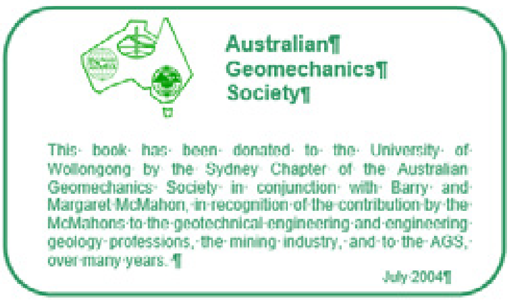
Emeritus Professor Robin Fell

- Fell, R., Macgregor, P. and Stapledon, D. (1992) *Geotechnical Engineering of Embankment Dams, Balkema Rotterdam*. This was a comprehensive text on the geotechnical and geological aspects of investigations; the design and construction of new dams; and the review and assessment of existing dams. This book has been influential world-wide, and a second edition has been published recently in 2018 by CRC Press, now entitled *Geotechnical Engineering of Dams*, with two additional authors, Graeme Bell and Mark Foster.
- Development of the RTA (now RMS) *Guide to Slope Risk Analysis* in the early 1990s, further refined in the late 1990s, early 2000s and mid-2010s, which provided a reproducible risk assessment framework that could be used by practitioners to produce Assessed Risk Levels for the several thousand slopes managed by RMS. This system has proved itself to be effective and has been adopted by other state government transport agencies in Australia and New Zealand.
- The advancement of unsaturated soil mechanics and computational geomechanics by Professor Nasser Khalili and his colleagues at the University of New South Wales
- The contributions through research and development towards the understanding of rail track by Distinguished Professor Buddhima Indraratna and his colleagues at the University of Wollongong.

Professor Nasser Khalili

Professor Buddhima Indraratna

- Recognition of the contributions made to *Australian Geomechanics* for the annual "Best Paper", to individuals such as (but not limited to) Wong, P. (2004), Burman, B. et al (2008), Hunter, A. and Hendrickx, M. (2009), Stone, P. C. (2012) and Chan, K. and Hull, T. (2017).
- Recognition of recent advancement in geomechanics knowledge throughout Australia through the E.H. Davis Memorial Lecture, with recipients such as Professor Daichao Sheng (2015), Professor Buddhima Indraratna (2009), Professor John Carter (2005), Late Professor Scott Sloan (2003), Professor John Small (2001), Professor Robin Fell (1999), Late Professor John Booker (1995), Dr Philip Pells (1993), Associate Professor Ian Johnston (1991), Professor Harry Poulos (1987) and Dr Barry McMahon (1985)
- Complementing the E.H. Davis Memorial Lecture, the AGS Practitioner Award recognizes contributions of the highest order over an extended period with a commitment to the geotechnical profession in Australia and the Australian Geomechanics Society. In NSW, the awardees include Andrew Leventhal (2010) and Professor Harry Poulos (2004).
- The donation of the McMahon Associates library in 2004 to the University of Wollongong, in honour of the contribution made by Barry and Margaret McMahon to the AGS, and the geotechnical, engineering geological and mining industry, over the course of many years



The ex-libris tag which was appended to those books purchased from the McMahon library and donated to the University of Wollongong.

In addition, Chapter members have participated in numerous AGS workshops and conferences, including various technical committees of the International Society for Soil Mechanics & Geotechnical Engineering (ISSMGE) and the International Association for Engineering Geology (IAEG).

It is the members of the AGS that have helped to drive the local and national practice to greater heights, and as such, several initiatives to grow the technical capabilities of the Sydney Chapter have been developed, including:

- The introduction of The Poulos Lecture in 2001, with the intent of giving recognition to an eminent speaker who has made distinguished contributions to the practice of geotechnical engineering or engineering geology

Harry Poulos and Neil Taylor, recipient of the 2004 Poulos Lecture (photo courtesy of Garry Mostyn)

- The Young Geotechnical Professional's Conference which promotes the work performed by younger geotechnical professionals from industry and within academia, and allows for their work to be presented to a wider audience
- The NSW Research Award Presentation Night which acknowledges the exciting and innovative research performed by some of the Chapters' geotechnical engineering research students
- An annual Debate Night, which allows for representatives from academia, consulting, construction and clients, to present their views on a variety of topics, including the transfer of risk from consultant to contractor and vice versa
- A Women in Geotechnical Engineering sub-committee, which aims to promote the role of women in STEM and within our industry, and host activities which highlight the key role diversity plays in our professional practice
- Regular technical talks throughout the year, which never fail to be interesting and sometimes generate a lively Q&A afterwards

When speaking of technical talks, we should mention the annual Symposium, first held in 1972 by the Sydney Chapter, on the topic of Monitoring of Dams. Later in 1997, the Chapter proposed an annual Symposium with the first topic being Pavement Design Beyond 2000.

A Symposium has been held every year since then, and has successfully covered a wide range of topics in geotechnical engineering. Every year, high ranking experts and industry leaders including prominent international speakers are invited to the Symposium to deliver technical presentations to an audience of about 200 people. The Symposium has always received strong support from leading companies and organisations as the sponsors. The valuable database of the Sydney Symposium proceedings is now accessible for AGS members through the AGS website.

Another note of pride is the adoption of new methods for reaching out to, and communicating with, members of the Sydney Chapter. The Sydney Chapter was the first to produce a website, and indeed registered the domain australiangeomechanics.org, for use by the Society. In addition, the Chapter has embraced social media, with a major presence on the AGS LinkedIn page (having contributed 20 of the 26 posts for the last 12 months!).

This willingness to embrace new ideas and innovation is reflected in the major projects being undertaken in the Sydney Region by members of the Chapter, including:

- Sydney Metro; a multi-stage, multi-billion dollar project encompassing 31 stations and 66 km of new metro rail, including several kilometres of tunnelling through Sydney sandstone, siltstone and the soft sediments below Sydney Harbour. It is the largest transportation construction project in Australia at this time.
- Rozelle Interchange; a new motorway interchange that is almost entirely underground, thus opening up nearly 10 hectares of open space and allowing for active transport options above.
- Western Sydney International (Nancy-Bird Walton) Airport; a significant infrastructure project to provide a second airport to service the growing number of passengers travelling from and to Sydney every year.
- The numerous Pacific Highway Upgrades; the largest road infrastructure project in Australia, with the vision to create approximately 650 km of four lane divided highway between northern Newcastle and the Queensland border, with numerous new sections of highway, new bridges and new interchanges.

Many of these projects have generated (and will generate) numerous research papers and articles, just as the world-leading dam and tunnel engineering of the Snowy Hydro scheme propelled Australian Geomechanics to the international stage.

It is no surprise that the thickness of the Australian Geomechanics Journal itself has grown substantially over the years, reflecting the compelling growth of papers and articles, with contributions both local and international.

It is the strong links between industry and academia, and between local and international geotechnical practitioners, that has helped forge the AGS into the collaborative and engaging entity that it is today. The successful bid to host the upcoming 20th International Conference on Soil Mechanics and Geotechnical Engineering (ICSMGE) in Sydney in 2021 has surely cemented the worldwide appreciation of our Australian Geomechanics Society and the contributions of AGS members to the community at large. We wish the AGS all the best during this Golden Anniversary year, and look forward to another 50 years of research, collaboration and engagement.

The 2008 AGS Sydney Chapter Symposium

The 2018 AGS Sydney Chapter Debate Night

The 2019 AGS Sydney Chapter Young Geotechnical Professionals Night

The 2019 AGS Sydney Chapter Research Award Presentation Night

This article was prepared by Jason Hellmuth, Buddhima Indraratna, Ali Parsa, Cholachat Rujikiatkamjorn and Sam Mirlatifi

Vignette from *Australian Geomechanics* 1978

Design Loadings for Foundations on Shale and Sandstone in the Sydney Region

P.J.N. Pells, D.J. Douglas, F.I.E. Aust., B. Rodway, M.I.E. Aust., C. Thorne, F.I.E. Aust., and B.K. McMahon, M.I.E. Aust.*

SUMMARY This paper considers the design of vertically loaded, isolated foundations located on or socketed into the sandstones and shales of the Sydney Basin. Inclined loading and loading near the edge of an excavation are not considered. A classification scheme for the shales and sandstones is proposed coupled with suggested allowable values for end bearing pressure and socket shear stress. These recommended pressures and shear stresses are based on limiting displacements to 1% of the socket or footing diameter.

1 INTRODUCTION

In May 1976 a sub-committee of the Sydney Geomechanics group was formed to review the situation regarding the design of foundations on the Sydney shales and sandstones. It was decided to limit the investigation to the bearing capacity and deformations of vertically loaded, isolated foundations that are located on, or socketed into level strata; interaction effects and the problems associated with founding near the edge of an existing or proposed excavation were thus specifically excluded. This work was prompted by various criticisms of the existing New South Wales Ordinance (Ordinance 70) that have been made from time to time, and by the existence of numerous cases where substantially higher stresses than those tabled in the Ordinance have been successfully carried, both by the Sydney rocks and also by similar or poorer quality rocks elsewhere.

This paper gives the results of the investigation and traces the sequence of study as follows:

(i) Existing legal requirements and design methods

(ii) Theoretical studies and laboratory data related to the bearing capacity of rock

(iii) Field tests on individual foundations on rock.

Based on these studies the paper culminates with guidelines for those designers, who, in accordance with the "let-out" clause in the existing Ordinance, wish to design for higher foundation pressures, where these can be justified following an appropriate site investigation.

2 EXISTING LEGAL REQUIREMENTS AND DESIGN METHODS

2.1 Ordinance Regulations

The legal document relevant to foundation loadings is Ordinance No.70 - Building, a Local Government ordinance which came into force in July 1974 and which applies throughout New South Wales with the exception of a few remote areas. Commonwealth and State Government Departments are not bound by the rules but the policy of these Departments is to endeavour to conform to them unless there are special reasons which justify departures.

Specific criticisms of the Ordinance include:

(a) It does not acknowledge the dependence of foundation behaviour on footing width

(b) The descriptive terms for the different rock types (e.g. soft shale, weathered rock, medium sandstone) are not defined

(c) All "defects" in a rock mass are treated alike, there being no concept of a graded significance to differentiate between say a strong shale layer in sandstone and a soft clay seam

(d) No consideration is given to socket shear.

However, it is clear that for structures whose foundation costs do not merit special design consideration, the Ordinance, in essentially its present form, provides a convenient and conservative approach, particularly where its provisions are applied with reasonableness and judgement. Hence this paper is directed primarily to situations in which significant financial savings can be made by increasing the foundation stresses above those given in the Ordinance 70 table. Ordinance 70 has, since 1974, made provision for the acceptance of higher foundation stresses through clause 32.3(i).

2.2 Existing Design Methods

A questionnaire circulated to engineering firms and organisations produced the following generalised picture of the existing design of foundations on Sydney shales and sandstones.

Practically all foundation designers recognize Ordinance 70 as the operative guideline and approximately 80% "usually" adopt the allowable bearing pressures listed in the Ordinance. Some 30% of those surveyed never use design values in excess of the Ordinance table even when obviously strong rock is available but about 15% "frequently" use higher values; foundations on uniform Ashfield shale, for example, have been designed on the basis of 2000 and 3000 kilopascals on a number of occasions and

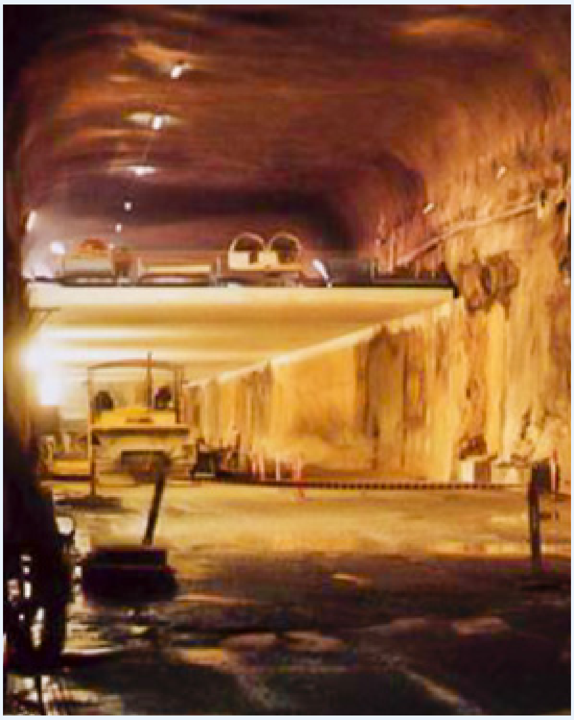
* Mr.Pells is a Lecturer in Civil Engg, University of Sydney; Mr.Douglas is Managing Director of Ground Test Pty.Ltd. Sydney; Mr.Rodway is Chief Engineer with Dept. of Construction, Sydney; Mr.Thorne is a partner in Coffey & Partners, Sydney and Dr. McMahon is a partner of McMahon, Burgess and Yeates, Sydney. (Paper S1015, submitted 12 May 1978).

NEW SOUTH WALES CHAPTER COMMITTEES

Year	Chairman	Secretary	National Representatives
1970	Mr Jack Hodgson	Mr Colin Thorne	Mr E Barnes, Mr N Worner
1971	Mr Jim Croft		Mr E Barnes, Prof Ian Lee, Prof John Jaeger
1972	Prof Ian Lee		Prof John C Jaeger, Prof Ian Lee
1973	Prof Ian Lee	Mr David Probert	Prof John C Jaeger, Prof Ian Lee
1974-75	Mr David Probert	Mr Don Douglas	Prof John C Jaeger, Prof Ian Lee
1976-77	Mr Don Douglas	Mr Peter Burgess	Mr Barry McMahon, Mr Colin Thorne
1978-79	Dr Peter Burgess	Dr Philip Pells	Dr Peter Burgess, Mr Doug Inkson
1980	Dr Harry Poulos	Mr Neil Mattes	Dr Harry Poulos, Mr Doug Inkson
1981	Dr Harry Poulos	Mr Neil Mattes	Dr Harry Poulos, Dr John Small
1982	Dr Philip Pells	Mr Garry Mostyn	Dr Philip Pells, Dr John Small
1983	Mr Max Ervin/Dr Laurie De Ambrosis	Mr Garry Mostyn	Dr Laurie De Ambrosis, Mr J P Harvey
1984-85	Mr Bruce Rodway	Mr Garry Mostyn	Mr Bruce Rodway, Mr Harvey
1986-87	Dr John Small	Mr Garry Mostyn	Mr Ian D Moore, Dr John Small
1988	Mr Garry Mostyn	Dr Terry Weisner	Mr Robert Carr, Mr Garry Mostyn
1989	Mr Garry Mostyn	Dr Tony Phillips	
1990	Mr Tony Phillips	Mr Bruce Walker	
1991	Mr Tony Phillips	Mr Bruce Walker	Mr Bruce Walker, Mr Tony Phillips
1992	Mr Bruce Walker	Dr Charles Gerrard	
1993	Mr Bruce Walker	Mr Peter Andrews	
1994	Mr Peter Andrews	Prof John Carter	Mr Peter Andrews
1995	Mr Peter Andrews	Prof John Carter	
1996-97	Prof John Carter	Mr Andrew Leventhal	Prof John Carter
1998-99	Mr Andrew Leventhal	Mr Geoff Young	Mr Andrew Leventhal
2000-01	Mr Geoff Young	Dr Craig Covil	Mr Geoff Young
2002-03	Mr Craig Covil	Mr Anthony Walker	Mr Anthony Walker
2004	Mr Anthony Walker	Mr Graham Scholey	Mr Anthony Walker
2005	Mr Graham Scholey	Ms Roberta Lindbeck	Mr Anthony Walker
2006	Mr Graham Scholey	Ms Roberta Lindbeck	Mr Graham Scholey
2007	Mr Henk Buys	Ms Roberta Lamont	Mr Mark Adams
2008	Mr Henk Buys	Ms Roberta Lamont	Mr Paul Hewitt
2009	Mr Mark Adams	Ms Roberta Lamont	Mr Paul Hewitt
2010	Mr Mark Adams	Ms Roberta Lamont	Mr Henk Buys
2011	Prof David Airey	Ms Sally Peacock	Mr Henk Buys
2012	Prof David Airey	Ms Sally Peacock	Mr Henk Buys
2013	Dr Hossien Taeibat	Ms Sally Peacock	Prof David Airey
2014	Prof David Airey	Ms Sally Peacock	Prof David Airey
2015	Dr Hadi Khabbaz	Mr Cillian McColgan	Prof David Airey
2016	Dr Hadi Khabbaz	Mr Ondrej Synac	Prof David Airey
2017	Prof David Airey	Mr Ondrej Synac	Prof David Airey
2018	Mr Sam Mirlatifi	Mr Ondrej Synac	Prof David Airey
2019	Mr Sam Mirlatifi	Mr Ondrej Synac	Mr Sam Mirlatifi

1990 TO 1999

GOING UNDERGROUND



Eastern Distributor Tunnel, Sydney, opened in 1999
Photograph from front cover of Australian
Geomechanics June 1999

GOING UNDERGROUND BY ROAD

Australia has a history of digging: Broken Hill mining, homes at Coober Pedy, tunnels for rail and water: Snowy Scheme, Poatina in Tasmania and Melbourne Underground Rail (MURLA,1981). In 1990 Sydney could only offer Bradfield's 1920 rail tunnels and a few others. But then the roads clogged, and all changed.

Almost simultaneously occurred the Sydney Harbour Tunnel (1992), the Opera House Carpark (1993) and the three Ocean Outfalls (1991). Initially design expertise came from Melbourne (ex-MURLA), but Sydneysiders caught up.

The Opera House Carpark cavern support is only rock reinforcement. Design combined linear arch theory and ideas from mining and from Poatina. Permanent support by rock reinforcement coupled with roadheader developments opened the floodgates. First the double-deck Eastern Distributor (1999); then M5 East (2001), Cross City and Lane Cove tunnels.

Road-tunnel fever spread to Melbourne (Burnley and Domain), Adelaide (Crafers), and then later to Brisbane (North South Bypass).

Now, in 2020, there are so many road tunnels under construction in Sydney, with spans reaching 24m, that what was bold design in 1990 is now commonplace.

THE SYDNEY HARBOUR TUNNEL

PATRICK WONG

Patrick has been a consulting geotechnical engineer since graduating from The University of Sydney with First Class Honours in Civil Engineering in 1978.

He joined the Coffey Group in 1979, and has held various leadership positions within Coffey including directorship of the operating company during the period 1991 to 1993, and Manager of Eastern Region during 1995 to 2000.

Patrick currently runs his own consultancy and also acts as a Senior Consultant at Coffey Services Australia Pty Ltd.

HISTORY IN THE MAKING

I was most fortunate to have been involved in the geotechnical investigation, design and construction of one of the great engineering feats of modern Australia; The Sydney Harbour Tunnel (SHT).

I got involved around 1986, and I was given the task of looking after the immersed tube section of the works under the supervision of Dr. Philip Pells, one of the modern day heroes of Geotechnical Engineering in Australia. I remember being so excited about the project. It was a big deal for me because it was the first immersed tube road tunnel in Australia at the time, and I knew that there were going to be many challenges and I would have the opportunity to learn from a bunch of experts on the subject.

Construction of SHT commenced in February 1988 and it was opened to traffic on 29 August 1992. Some of the interesting facts about the birth of the SHT include the following:

- Who would have thought that a tunnel crossing of Sydney Harbour was suggested as early as 1885, way before even my grandfather was born? Instead of a tunnel though, the iconic Sydney Harbour Bridge was built in 1932.
- By the '70s though, traffic across the bridge was becoming a nightmare (sound familiar to current days?), so in 1979, the NSW Government called for alternative traffic solutions, including proposals for both bridges and tunnels. All proposals submitted involved the demolition of a large number of dwellings on both sides of the harbour. As a consequence, all proposals were rejected.
- In 1984, Consulting firm Wargon Chapman and Partners approached Transfield to study a solution to build a tunnel without affecting any of the dwellings to the north and south of the bridge (see Figure 1).
- However there is a less well known and very interesting story behind who came up with the idea of the tunnel alignment. According to Alf Neilson, one of the partners of Wargon Chapman at the time:

  "About 6 years ago now we were approached by a guy who was an old friend of the company's who, with some of his associates, had an idea for a tunnel and they came to us with a route marked up on some road maps and we took that concept and developed it into what we thought was an engineering solution to a problem that we recognised."

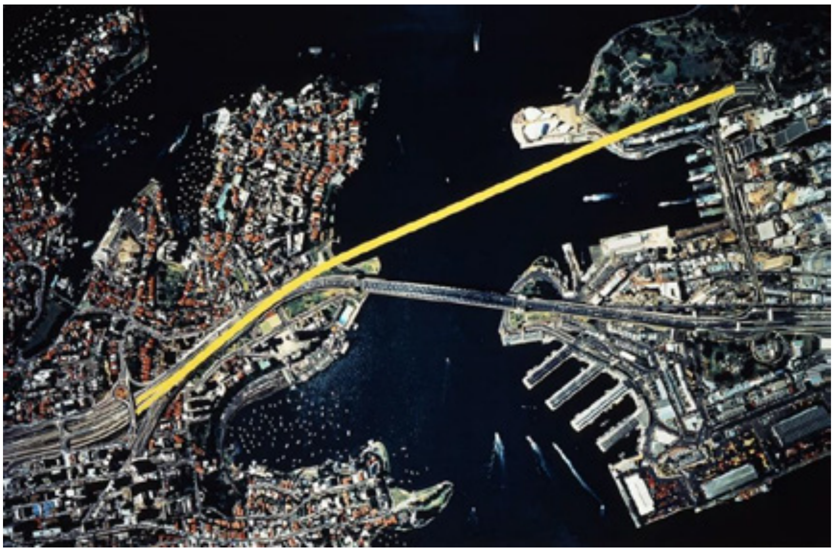


Figure 1: Plan of the SHT Route (courtesy of Transfield)

1990-1999

- Tony Shepherd, a director of Transfield Constructions at the time, took the idea to the Board and they immediately seized the opportunity. Transfield in turn approached Kumagai Gumi a large Japanese construction company with extensive experience in tunnel construction and immersed tube technology. Thus a joint venture was formed between Transfield and Kumagai Gumi (TKGJV).
- According to Transfield (1956-2016):

  "*A crucial meeting took place in the cafeteria at Level 13 of Transfield House in North Sydney, in clear view of Sydney's Harbour Bridge. In attendance were the company executive Tony Shepherd and its consulting accountant, John Scott, engineers Alex Wargon, Reg Hornibrook and Corbett Gore. Kumagai Gumi was represented by Tony Mitani. Alex Wargon laid the plans on the table and all looked out of the window at how the tunnel could be constructed. The solution devised seemed very clever - no buildings needed to be demolished and the new road tunnel could be incorporated into the existing network on both sides of the harbour. The ventilation stacks were run through the existing northern pylons of the Bridge.*"
- TKGJV proposed a Build Own Operate and Transfer package to the NSW Government, to privately finance and build the SHT. With traffic worsening by the day, Cabinet eventually approved the contract in April 1987 without the usual tendering process. This was very clever of TKGJV but not without risk as they had invested several million dollars in developing a feasible solution before taking the proposal to the Government.
- The $750 million tunnel was at the time the largest privately financed infrastructure in Australia.

THE GEOTECHNICS

The geotechnical investigations for the land tunnels were primarily looked after by Dr. Philip Pells, and I looked after the investigations for the Immersed Tube Tunnels (IMT).

The majority of the land tunnels was constructed within good quality Hawkesbury Sandstone, and geotechnical investigations focused particularly on cuttability and abrasive characteristics of the rock. Careful attention was paid to developing accurate models for conditions at both the southern and northern approaches where the interface connection must be made between the immersed tube and the land tunnels. Considerable attention was also paid to the ventilation building at Bradfield Park, as it was known from old photographs that there was a quarry in the area more than 130 years ago; there were excavations for harbour works some 110 years ago; and further excavations for construction of the Sydney Harbour Bridge some 80 years ago.

Across the harbour along the route of the IMT, the subsurface profile and conditions are in stark contrast to the land tunnels. The IMT were constructed in unconsolidated marine sediments which extend down to RL -45 m at the deepest point of the paleo valley as shown in Figure 2. It is postulated that Pleistocene deposition occurred up to at least RL -15 m. In some areas these deposits have been subsequently eroded down to about RL -35 m, presumably during the most recent sea level low between 17,000 and 10,000 years BP, when the sea level probably fell as low as RL -80 m. Between 10,000 and 6,500 years BP, during the Pleistocene period, the sea level rose steadily to its present level, submerging the eroded land surface. Deposition mainly of sands, silty sands and clayey sands with varying proportions of shells and shell fragments, occurred up to the level of the present harbour floor.

Geotechnical investigations for the IMT involved state-of-the-art self-boring pressuremeter (SBPM) testing from a jack-up barge (note: Ex Coffey Managing Director, Roger Olds was on hand to provide training to the SBPM operator and geotechnical engineer during the investigation). One of the challenges during the investigation was all the marine craft movements in the harbour and we had to follow strict instructions of the Harbour Master.

More details of the geotechnical investigations and geotechnical conditions along the tunnel route can be found in Pells and Wong (1990).

At Port Kembla, the geotechnical challenges for the casting basin included slope instability of the cofferdam side walls which were in a thick upper soft clay unit and stopping leakage of the sheetpile wall across the cofferdam which was constructed using sand and rockfill. Also, despite continuous dewatering, gravel fill relief wells had to be installed within the base of the cofferdam to prevent heaving of the floor due to artesian pressures. And when it was time for the sheetpiles to be removed for floating the IMT units out, some of the sheetpiles had to be "blown-out" by underwater explosives because they had been driven too far into the underlying bedrock.

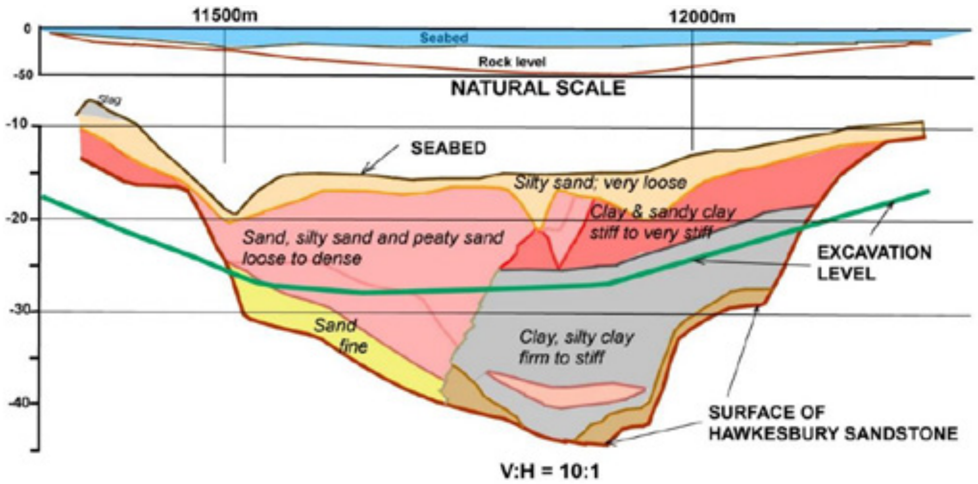


Figure 2: Inferred Geological Section across the IMT Route (courtesy of Dr Philip Pells)

THE CONSTRUCTION

Design of the tunnels was managed by Wargan Chapman (now Arcadis) with the design team comprising MacDonald Wagner (harbour tunnel) and John Connell (land tunnels).

The tunnel is made up of three sections: twin 900 m long land tunnels on the north shore; twin 400 m long land tunnels on the south shore; and a 960 m long IMT structure. The tunnel falls about 55 m from the northern entrance and about 35 m from the southern entrance to its deepest point at 25 m below the sea level.

The technology used for the construction of the IMT was very advanced for Australia at that time. The eight reinforced concrete tube units, each 120 m long x 26 m wide x 7.7 m high x 23,000 tonnes in weight, were constructed over 100 km away in a casting basin at Port Kembla (see Figures 3 and 4) and then towed to Sydney Harbour. It was a world-first for reinforced concrete tunnel units of such size to be towed in the open sea (see Figure 5).

Figure 3: Casting Basin for the Construction of the IMT Units at Port Kembla (courtesy of Transfield)

Figure 4: Close up of IMT structure being constructed at Port Kembla (courtesy of Ms Margaret Rush)

Figure 5: An IMT Unit being towed out of the Cofferdam at Port Kembla (courtesy of Ms Margaret Rush)

Across the harbour, a trench was dredged by Westham Dredging Company to receive the IMT units which were lowered into the trench by a system of pontoons and control towers. Short-term stability of the trench, bearing capacity and settlement characteristics of the founding materials were the main geotechnical design issues.

Temporary footings and jacks were used to level the units before backfilling the underside of the IMT units and around the trench. Rock armour was then placed over the top of the units to protect them against potential marine hazards such as ship anchors and scour.

Immediately after sinking, the IMT units were supported on jacking pads until the 1 m void between the IMT soffit and the foundation was filled by sand jetting. The stage prior to completion of the sand bed was most critical with respect to bearing capacity of the foundation soil for the temporary supports when each supoort has to carry a concentrated load of 2,500 kN.

Another challenge of the project was the aggressiveness of the marine environment to the IMT units. Whilst concrete totally immersed in seawater would normally be "low risk", the presence of chloride in sea water and oxygen within the immersed tube contributes to a greater than normal risk. The rate of chloride penetration is directly linked to the permeability of the concrete matrix.

After much research and testing by the structural engineers, the cement used on the project was the ACSE ground granulated blast furnace slag and the coarse aggregate was basalt from Dunmore Quarry. According to Transfield,

> *"The land tunnels were constructed by a combination of driving and cut-and-cover techniques, designed to be strong enough to withstand the impact of earthquakes.*
>
> *Work on the south shore of the harbour was the most complex and demanding. Beneath the Opera House forecourt, the land-marine transition structure was only accessible by tunnelling, and was constructed entirely underground. A large Moreton Bay fig, its roots just over the tunnel system, had to be preserved at all cost. As excavation was proceeding, the tree root system was propped up from within the tunnel, at a cost of $500k. "It was a bit like watching grass grow", quipped an engineer.*
>
> *Tunnelling on the northern side of the harbour and excavations for the two ventilation stations presented similarly challenging problems, in particular digging under the sea level and connecting and driving the ventilation systems through and up the two northern pylons of the bridge."*

Figure 6: An IMT unit in position ready for sinking (courtesy of Ms Margaret Rush)

ACKNOWLEDGEMENT

It was a fantastic learning experience for me, I met some extraordinary people and engineers. Amongst them were my mentor and friend, Dr. Philip Pells; Alex Chapman and Alf Neilson of Wargon Chapman; Franco and Tony Shepherd of Transfield. Roger Olds taught me some useful tips in SBPM testing and electronic repairs to the equipment, and Ross Best gave me hydrogeological support for the challenges faced at the IMT casting basin.

I thank Sydney Harbour Tunnel Company and Ms Margaret Rush (Official Photographer at the time) for supplying the construction photographs.

Finally, I am grateful to Dr. Philip Pells for urging me to write this article, offering me guidance, redrawing the geological section across the harbour in colour and assisting me in obtaining some of the project photographs.

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Figure 7: A happy bunch of engineers at Port Kembla (courtesy of Ms Margaret Rush)

MAX ERVIN CHAIR 1991–93

………. I had discovered that most Europeans were afraid of the distance to travel to Melbourne, so being able to catch a train was appealing, regardless of the compelling reasons why the INTERNATIONAL Society should respect ALL of its regions, not just Europe! …As it turned out the vote was tied!! The then President of the Society proposed that this impasse be decided by the toss of a coin!! We lost and so we all trouped off to Hamburg in 1997…………

I have been asked to provide some reflections on the geotechnical community in the period 1991 – 1993, at the time I was Chairman of AGS. Given I have trouble remembering what happened last week, this is a significant ask, especially as I have retired and left my library and associated records of those times (including what must be close to a complete set of Australian Geomechanics (and The Australian Geomechanics Journal before that), to the Golder Foundation, and so don't have ready access to them. However, I do recall they were interesting times with some great projects happening, at least in Melbourne where I was based.

With respect to the AGS, I was privileged to serve on the National Committee initially, as I recall, from 1977 to 1979, and then, after a stint in Sydney, from 1984 through to 1997. This was initially as Victoria Group National Committee representative, and then 3 years as Vice Chairman, 3 years as Chairman, and then I moved on to the old f**t status of Past Chairman, during which time I was elected to represent Australia and New Zealand as Vice-President for Australasia on the ISSMFE (as it was then) Board. Recognising the long path typically required to make it to Chairman, if that was what was to happen, I recall recommending to the National Committee that the term of Chairman be reduced from the usual 3 years to 2 years. The Committee agreed, but I recall the Deputy Chairman of the time (Garry Mostyn I believe) saying that despite the recommendation being accepted, I should serve out the extra year to make my term still 3 years! Thanks Garry.

I really did enjoy those times on National Committee – many happy memories and a number of stories which could be told, but not committed to print!! I do recall one of the roles I had as Chairman was to attend the Civil College Board meetings. I remember presenting my AGS report (as a National Committee of the Civil College) and taking great pleasure in reminding those assembled that the AGS, through its precursor the National Committee on Soil Mechanics and Foundation Engineering, had been around since 1953, and as such I think for longer than any other National Committee.

Given we were "a Society" the AGS was somewhat considered as a body to be tolerated, but given the Society achieved much including successful seminars and Regional Conferences, and charged our Members for the privilege of being a Member, the College couldn't do much about us!

For many years the AGS was very well supported by Roy Bushnell as the IEAust appointed Secretary. Roy always looked out for us. I can't recall the exact timing, but after Roy retired we were assigned a new Secretary, I suspect in about 1989 or thereabouts. I feel this person should remain nameless, for it is fair to say he did not provide effective or willing support to the Society. Many were the heated discussions in National Committee meetings seeking outcomes or assurances, with as I recall Garry Mostyn being particularly acerbic and insightful on more than one occasion. However, those times thankfully passed and Peter May came on board. What a breath of fresh air was Peter – he went out of his way to look after the Society, and was a real asset to the AGS at the time. If you happen to read this Peter, thanks once again.

In 1987 the AGS decided to have a tilt at hosting the 1993 ICSMFE, with our competition being India. I remember presenting our bid in Dublin, and keeping to the allocated time of 10 minutes, to then be followed by the Indian delegation who held the floor for 45 minutes and were not stopped. Promises of Maharajah Class flying Air India, and many other delights! They were successful, leaving us more determined than ever to host an International Conference.

With strong support from Melbourne Tourism and the Institution, as well as the commitment from AGS, we went all out. I was pleased to have led that charge and made presentations at the 1989 Rio Conference, at a number of Regional conferences, and any other time the opportunity presented itself.

The big day came at the ICSMFE in Florence (1991) with the alternative offer coming from Hamburg. I believe we made a very professional and compelling presentation (I ignored the 10 minute limit!), whilst our German friends showed a video prepared by the Hamburg Tourism Authority, highlighting the ease of travel, etc. but with no reference to the International Society or what the Conference might provide to attract delegate interest!

One has to remember that the ISSMFE Council had a majority (or close to it) of European Members, so we were up against it before we started. I had discovered that most Europeans were afraid of the distance to travel to Melbourne, so being able to catch a train was appealing, regardless of the compelling reasons why the INTERNATIONAL Society should respect ALL of its regions, not just Europe! As it turned out the vote was tied!! The then President of the Society proposed that this impasse be decided by the toss of a coin!! We lost and so we all trouped off to Hamburg in 1997.

Those who attended the Hamburg Conference will recall threats of the beer being turned off if silence was not provided for some speeches no one needed to hear; the absolute bun fight at the pre-dinner reception with an overcapacity crowd sandwiched into a hot hall, with drinks and canapes being served from one corner of the room (If 5% of those in attendance got a drink, I may be exaggerating!); and the wonderful arrangements in place to pay for your drinks at the Conference dinner! Anyway, after that fiasco, the Victoria Division of AGS decided enough was enough, but happily Mark Randolph and his colleagues in Perth stepped up to try for Australia (this time Perth) yet again. Off we all went to Cairo in 1995, only to face yet another European coup with the Conference being awarded to Istanbul. So much for an International Society after that embarrassment!

The consolation prize offered to Australia was to host what became GeoEng2000, a joint conference of ISSMGE, ISRM and IAEG, with IGS, ITA and IAH also tacking on as Supporting Members. That conference was a great success and showed the geotechnical world what Australia could achieve if given the opportunity.

We are now in the wonderful position, thanks to the considerable efforts and energy of Graham Scholey and his colleagues, to be hosting the next ICSMGE in Sydney in 2021.

Pressuremeter Testing for Foundation Investigation

M.C. ERVIN

Coffey and Partners Pty Ltd, Sydney

1. INTRODUCTION

Modern developments, such as the finite element method, have resulted in increasingly sophisticated techniques of analysis for problems in soil mechanics. These improved methods have highlighted the problems inherent in conventional sampling and laboratory testing. Often these testing procedures cannot supply sufficiently accurate parameters for even conventional design calculations. This is particularly relevant to deformation properties.

It is widely accepted that the action of "sampling" causes significant disturbance, both due to mechanical deformation and to the inevitable difference in stress history of a laboratory soil sample and a similar element in the field. A number of authors have demonstrated the differences between back analysis of field observations and laboratory testing, again in particular for moduli determinations.

Another constraint frequently thrust upon us by cost limitations, transport facilities or mere practicability is the size of laboratory specimens tested. Undisturbed samples recovered during commercial foundation investigations are usually 50mm diameter, with the not often enough resort to 75mm diameter samples when "high class" samples are required. These larger samples are usually specified for soft ground conditions, where the effects of sample disturbance are more often acknowledged (lower area ratio with larger sample tube), or when the influence of soil fabric, such as fissuring, is recognized. However, soil fabric, not only in the form of fissures, but as root holes, silt and sand partings, etc. often is not adequately represented.

In the case of foundations to be constructed on rock, the influence of the rock mass behaviour (i.e. the fabric) on the behaviour rather than the intact rock properties is well recognized. Regrettably, with rock we are faced with a greater or at least more easily recognized problem with respect to sampling and testing.

weathered rocks, similarly, often behave as high strength soil, except that jointing and other inherent mass defects may govern overall behaviour. Insitu testing to obtain strength and deformation parameters is frequently the only means available unless highly empirical relationships with such index properties as moisture content are adopted.

Various forms of insitu testing have been proposed to overcome the problem alluded to above. In practice, the simpler forms of such insitu testing have been widely adopted. There are, nevertheless, many problems associated with insitu testing, of which the difficulties of following a given stress path and the need to test very quickly to simulate undrained conditions are just examples. Despite this, and without suggesting that laboratory testing can be dispensed with, appropriate insitu testing can replace some routine laboratory testing and yield more reliable and possibly more economic results.

Of the many forms of insitu testing available, each has advantages and disadvantages, but for the purpose of this paper only the use of insitu pressuremeter testing will be considered. Such testing is reasonably economical and allows direct measurement of deformation properties and, more so in soils, of shear strength using well developed theories. Of particular advantage is that there is virtually no restriction on the depth at which testing can be carried out.

2. DEVELOPMENT OF PRESSUREMETER TESTING

The pressuremeter as conventionally known today was initially developed by Ménard as a final year project (1954) and was a reality in commercial practice by 1957 (25 years ago). Kögler, however, discovered the use of a similar inflatable borehole testing device as early as 1930, but had difficulty in interpreting the test results.

Vignette from *Australian Geomechanics* April 1983

1990-1999

THE SYDNEY OPERA HOUSE CAR PARK

PROFESSOR PHILIP PELLS

Philip Pells grew up in South Africa, undertaking post-graduate studies at Imperial College. He took a post at Sydney University in 1975 as lecturer in rock mechanics, and in 1980 moved to the consulting industry becoming a Director of Coffey & Partners in 1990. He co-founded the consultancy, Pells Sullivan Meynink (PSM) in 1993, the same year he was awarded Doctor of Science.

He was Chairman of the Sydney Division of the Australian Geomechanics Society in the late 1980s and published 25 papers in the Australian Geomechanics Journal between 1975 and 2019.

THE ODD ORIGINS OF BRILLIANCE

The Sydney Opera House Carpark was not supposed to be as it is.

The Sydney Opera House is widely accepted as one of the great buildings, possibly the greatest, of the 20th century. For more than a decade after its completion in 1973 the absence of parking within reasonable distance presented great difficulties for the 2000 or more attendees. After false starts over more than 15 years, the New South Wales Government put out a tender in early 1990 for private enterprise to build and operate an 1100 vehicle underground parking station. The facility was required to be built in a restricted footprint area beneath the Botanic Gardens, only a few hundred metres from the Opera House forecourt.

I was part of a team that submitted a design on behalf of the Mulpha Group that comprised two side-by-side rectangular underground structures with cross connections at the ends. Each rectangular structure was much like a traditional above-ground parking station, with narrow ramps and tight corners. And if you were the last patron in either structure you would have to wind your way down seven or eight levels and occupy the last place in the bottom corner. The design had other unattractive features. Ventilation of the two chambers was difficult and expensive, and egress stairs eliminated a significant number of valuable parking spaces. Much to the surprise of some of us, Mulpha's submission was accepted by the Government. Basically the competitors' designs were much the same and Mulpha had a better financial deal.

The award was made on a Friday. I went home. However, the key members of the design team (structural engineer Warwick Colefax, civil engineer Tony Barry and architect Ron Barelle) met in the engineers' board room to celebrate and to discuss the win over a few beers. Their main concern was that they were unimpressed with the design they had submitted and they felt that something unique and innovative was needed for such a prestigious venue.

The design they had submitted was a very traditional design for an above-ground car park and they had simply placed it in a pair of tunnels below ground. They had raised these concerns with the client during the submission process but Neil Fimeri was correct in saying it was not the design that was going to win the project, it was the commercial aspects of the submission. He said "Let's worry about that after we win."

Well the time had come and the team was at a loss to come up with something original. Then Ron Barrelle had an idea. He said in his travels he had seen an above-ground parking station in Paris that was a double helix with a void up the centre that acted as a natural ventilation stack. Air was drawn in around the entire circumference and escaped up through the void to the outside. Warwick patiently pointed out that this would not work underground, especially as the car park was under the Botanic Gardens and they were not permitted to break through the surface at any point. But then, probably encouraged by the contents (more than the shape) of a few more beer cans the lights flickered on and they started to sketch.

Within a few hours they had developed the outline of a concept of a 30m deep cavern, circular in plan with a central rock pillar (in place of the 'Paris' ventilation stack). This donut shaped cavern contained a double helix reinforced concrete structure that could be interconnected at any location simply by tunnelling horizontally through the central pillar of rock. The gently sloping ramps of the helix provided for parking and access. Now the last parking place was not at the bottom, but at the top. Ventilation was easy; only one cavern. Travel distances were minimised and hence the required number of fire stairs was also reduced.

The total volume of excavation was reduced, and lo and behold, it could be fitted within the originally allocated development boundaries. The footprint area was reduced from 7900 square metres to 3000 square metres.

1990-1999

A stringent condition of tender was that under no circumstances was the ground surface in the Botanic Gardens to be disturbed for any purpose, so the only question was; could such a cavern be built, with only 6m of rock cover? On the Monday I turned up at work at Coffey and Partners, oblivious of Friday's beer befuddled discussion, and the detailed work that had followed over the weekend. Mid-morning I received a fax and a phone call. Simple question; could such a cavern be built? I had never seen anything like it. Nobody had, because it had never been done before.

If one is very fortunate then maybe once in a lifetime one will see a concept or design of sheer brilliance. That's what I saw that morning. And we at Coffey concluded that the cavern could be built with no disturbances to the ground surface.

Figure 1: Location plan

A UNIQUE STRUCTURE

The Carpark is unique in shape and size, and is the first helical underground parking station.

A 12story free-standing double-helix concrete structure, for 1100 cars, is housed in a doughnut-shaped cavern, with a span of up to 19m and an outer radius of 75m. The concrete structure does not provide long-term support for the rock; it does not touch the sidewalls or the roof of the cavern.

With cover thickness of Hawkesbury Sandstone about a third of the span, the roof is the key feature of the cavern. It is not supported with a formed concrete arch but by internal reinforcement comprising tensioned Macalloy bar anchors up to 7.5m long and un-tensioned galvanized dowels up to 4.5m long. There are about 2000 anchors and dowels in the roof (see Figure 2).

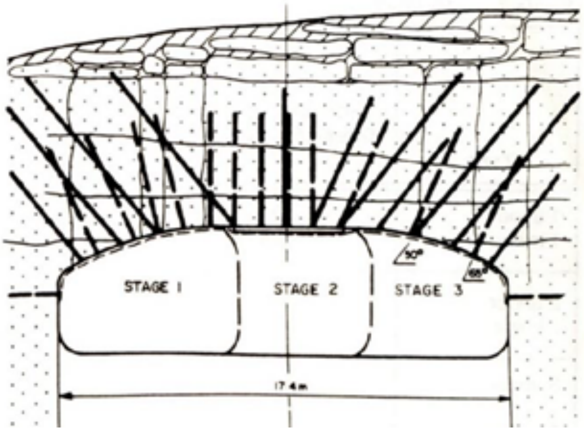

Figure 2: Cavern roof permanent support

Key design features of the roof are:

- it is almost flat, as this is found from both analytical studies and experience to be appropriate in horizontally bedded strata with a relatively high horizontal stress field ($\sigma_h/\sigma_v \approx 2$ to 5);
- the reinforcing elements were designed so as to tie together the horizontal beds of sandstone (ranging in thickness from 1m to 3m) to act as a single pseudo-elastic no-tension linear arch; and
- the surface is covered with a 150mm skin of reinforced shotcrete which acts as a membrane between the reinforcing elements.

Other special challenges were:

- portions of the underground excavations are beneath outbuildings of Government House (see Figure 1);
- the cavern is within 60m of Sydney Harbour and extends 28m below sea level; all work had to be done without disrupting the surface other than for the two 9m wide access tunnels which have to pass over the Sydney Harbour Tunnel and have, in places, rock cover as low as 2.5m; and
- 16 tunnels had to be excavated ranging in span from 2m to 12m for access and ventilation.

For 20 years it was thought that the Opera House Carpark cavern was the widest shallow-cover rock cavern in the world (see Figure 3). Then in 2015 I learned of the 2000 year old caverns in sandstone at Longyou south west of Shanghai. They are to my mind the most amazing underground excavations I have heard of (Pells, 2017).

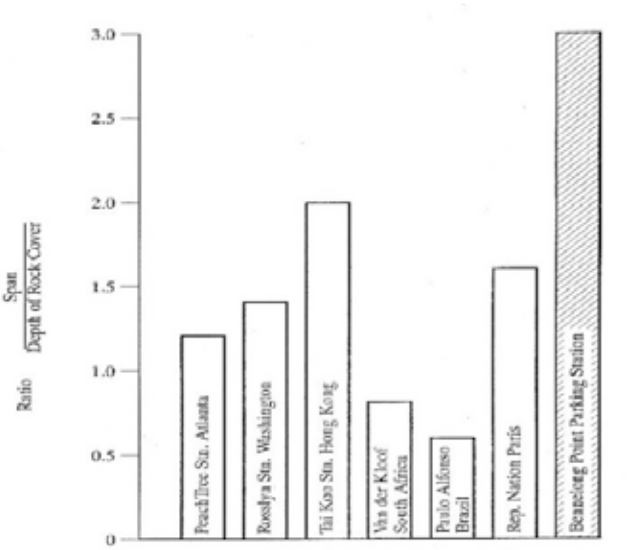

Figure 3: Comparison of rock cover versus span for several large near-surface rock caverns

EXCAVATION, SUPPORT AND MONITORING

Excavation of the access tunnels (Photograph 1) and the crown section of the main cavern was by a Mitsui S200 roadheader. This machine proved to be the first roadheader which could cut the high silica content Hawkesbury Sandstone (75% to 85% silt and sand size quartz) with reasonable productivity and pick-wear rate. A small S65 machine was also used for a 1.6m wide tunnel required for diversion of an old storm water tunnel.

Photograph 1: Excavated vehicle access tunnel connecting to cavern in the distance

The crown section of the main cavern was excavated by successive widening from an initial outer 6m wide heading. Support was installed as the heading was widened from 6m to 10m and then to 18m. Careful monitoring of roof deflections, rock anchor loads and roof delamination was undertaken as the span increased, as a check against design assumptions.

Once the crown was fully excavated and supported, a D10 bulldozer (Photograph 2) fitted with an impact ripper was used for bulk excavation.

Photograph 2: D10 bulldozer used for bulk excavation in the cavern

The cavern walls were trimmed with hydraulic impact breakers, also used to cut slots up the cavern walls for ventilation risers and the lift shaft (see Photographs 2 to 4).

Photograph 3: The 32m diameter central core showing slots for ventilation

Corrosion protection of the anchors and dowels in the crown of the main cavern and in the various service tunnels involved the following philosophy for the specified 50 year design life:

- the tensioned Macalloy bars are epoxy coated and full column grouted in a high early strength Portland cement based grout;
- the untensioned dowels are hot dip galvanised and also full column cement grouted; and
- all major support elements in the main cavern are accessible and can be replaced if significant degradation due to corrosion occurs in the long term.

Photograph 4: Slots cut in side of cavern for the lifts and ventilation risers

Instrumentation of the cavern included multipoint extensometers installed from the ground surface prior, inclinometers installed around the perimeter and in the core, sag measurement points on the cavern roof, a subsidence grid on the ground above the cavern, instrumented anchors, and a piezometer network. Measured crown sag showed good agreement with design predictions (see Figure 4).

Excavation of the cavern and associated tunnels, involving some 130,000m^3 of sandstone, started in late 1990 and was completed in April 1992.

At that stage we decided to have a formal dinner at the base of the cavern. This involved lowering an oven for the chef and all the other niceties. Photograph 6 gives a view of the tables from the top of the cavern, while Photograph 5 is Neil Fimeri, Mulpha's project director extraordinaire, giving thanks that the cavern had not collapsed.

The twelve story concrete helix was completed in September 1992 and the parking station opened March 17, 1993, six months ahead of schedule.

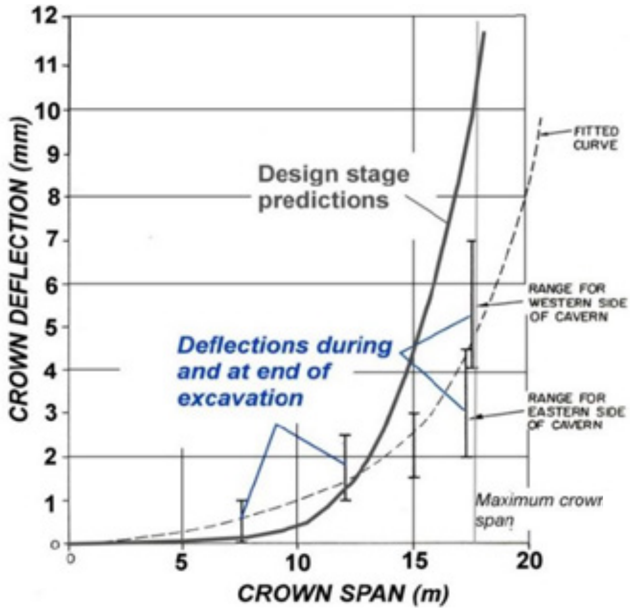

Figure 4: Surface settlements compared with predictions

Photograph 5: Neil Fimeri – the man who made it happen

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Photograph 6: Formal dinner on the floor of the cavern

GARRY MOSTYN CHAIR 1994-95

The first ANZ young geotechnical professionals (YGP) conference was held at the University of New South Wales between 9th and 12th of February 1994 and attended by 36 registrants, with 8 from New Zealand and 1 from Papua New Guinea.

The AGS had been left in great shape by prior National Committees and very much reflected a common position:

- We were and still are sponsored by both IEAust and AusIMM and thus had effectively no master (I thank many persons for this but especially Max Ervin). This generated a continuing tension with IEAust; in fact that was business as usual.
- We were active, especially in publishing Australian Geomechanics; then and now, a showpiece for a technical society.
- We fostered active local groups. The AGS had over 40 well attended local technical meetings annually, often the most of any technical specialty within either of our sponsors.

We were moving towards hosting GeoEng2000, the first ever international conference of ISSMGE, ISRM and IAEG. The ANZ conferences had been such for a long time.

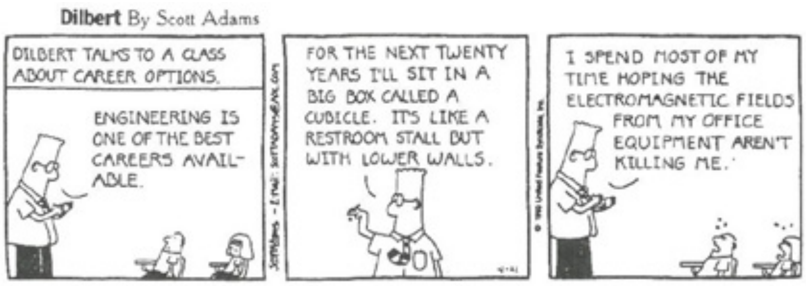
An issue that I remember was that the editorship of Australian Geomechanics was voluntary and rotated through the groups. It had usually been in the hands of an academic and the time constraints on academics was becoming more overwhelming. Australian Geomechanics was issued twice a year and was often quite late. I think this was the time we decided to move to quarterly issues and a small stipend for the editor.

Clearly we were working towards the ANZ conference in Adelaide in 1996.

National Committee Members

Chairman	Mr Garry Mostyn	University of NSW
Deputy Chairman	Dr Tony Phillips	Arup Geotechnics
Immediate Past Chairman	Mr Max Ervin	Golder Associates
Australian Vice Presidents		
ISSMFE	Prof Harry Poulos	Coffey Partners Int
ISRM	Prof Michael Pender	Univ. of Auckland, NZ
IAEG	Mr John Braybrooke	DJ Douglas & Partners
IE Aust Nominee	Dr Charles Waterton	Dames & Moore
AustIMM Nominee	Dr Sandy Bennet	Connell Wagner Group
Elected Members		
NSW & ACT	Mr Peter Andrews	DJ Dougals & Partners
Queensland	Mr Robert Morphet	Golder Associates
SA & NT	Mr Don Cameron	University of SA
Tasmania	Mr Randal Colman	HEC Scientific Labs
Victoria & Overseas	Dr Chris Haberfield	Monash University
	Mr Brian Chandler	Maunsell Pty Ltd
WA	Mr Trevor Osborne	MPA Williams & Assoc.
Newcastle	Dr Scott Sloan	Univ. of Newcastle
Secretary	Mr Peter May	IEAust

Australian Geomechanics – October 1994



Vignettes from *Australian Geomechanics*, October 1994

NATIONAL COMMITTEE MATTERS

CHAIRMAN'S CORNER

by Garry Mostyn

This is my first *Chairman's Corner* and I start it with some sadness. Roy Bushnell, the Society's immediate past secretary/executive officer, died on 27th June. Roy was a very happy and efficient secretary who was a valuable ally of the AGS. I am sure he will be warmly remembered by all members of the National Committees he served and any others that he came in contact with.

The National Committee membership changes regularly. John Braybrooke has completed his term as regional Vice President of the IAEG and Dr Warwick Prebble, of New Zealand, succeeds him. Harry Poulos has finished his term as regional Vice President of ISSMFE and is succeeded by Max Ervin. This change of roles has left the National Committee without Harry Poulos, this is new territory for almost all the members (Max himself is probably the only exception). I would like to publicly thank Harry for the endless good counsel that he has provided to the Committee over the years and to express the hope that it will be available informally in the years to come.

Part of the Society's review of itself should be in this issue, that is a draft set of revised statutes. The most significant change is that the size of the committee is reduced with Victoria & Overseas, New South Wales, IEA and AusIMM all having representation reduced from two to one member. Further the Editor of this journal becomes a non-voting member of the committee. These revised statutes are to be submitted to our sponsoring bodies, so if you have any comments please let me or Chris Haberfield know as soon as possible. With the reduction in size it is important that the State Representatives represent their entire states, especially where there is more than one active group (as in NSW and WA). I will endeavour to ensure that this happens.

Perth is mounting a bid for the 15th International Conference on Soil Mechanics and Foundation Engineering to be held in 2001. I believe their bid will be one of the strongest and, if they are successful, the conference will be a very significant point in Australian geomechanics.

All members should have received (or be about to receive) a questionnaire regarding the services that the AGS provides, the National Committee is very keen to learn how you value these, what additional services you would value and how we can provide better service in future. Please fill out the questionnaire and return it, your advice is keenly sought. The questionnaire is also being sent to those members from 1993 who have not renewed their subscriptions in an attempt to find out why. A further questionnaire is being sent to our Supporting Members for their input. These are all part of the National Committee's efforts to continually inform itself of the society's members' views.

One of the questions on the questionnaire is as to whether you think that the AGS (or in fact IEA) should register Geotechnical Engineers. This has been prompted by the Institution's recent moves towards subdiscipline registration. The National Committee was strongly of the view that registration should be at College level, ie Civil Engineers only, and that any further subdivision was likely to be difficult to achieve and of little value. I believe that this was the view of virtually all the other National Committees with the exception of the NC on Structural Engineering. It appears that an acceptable compromise has been reached where registration will beat the level of Civil Engineer, with Structural Engineering as the only subdiscipline. I believe that the members of our National Committee will be very happy with this outcome.

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Vignette from *Australian Geomechanics*, October 1994

REMEDIAL WORKS FOR THE BURNLEY TUNNEL, MELBOURNE

PROFESSOR PHILIP PELLS

GRAEME PECK

Philip Pells moved from lecturer in rock mechanics at Sydney University to the consulting industry in 1980. He co-founded the consultancy, Pells Sullivan Meynink (PSM) in 1993.

Graeme Peck spent a decade as Director of Pearson Bridge, operating in civil and marine works throughout Australia and SE Asia. He co-founded the construction consultancy Evans & Peck, in 1985.

Philip and Graeme filled roles on several of the same major projects including the Ski Tube, the Sydney Harbour Tunnel, Concept Design for the North-South Bypass, Brisbane, and the Burnley Tunnel remediation.

INTRODUCTION

In September 1999, just when it was expected that the 2.8km long Burnley Tunnel beneath the Yarra River would open for traffic and thereby complete the 22km long Melbourne City Link, portions of the invert of the tunnel started to fail under the 60m hydrostatic loading.

The tunnel was successfully remediated but at great cost, opening more than a year behind schedule. The potential for damaging settlements over significant parts of the commercial and sporting-complex area of South Melbourne was averted.

Here we tell the story of our involvement in the remediation works, reflecting not only on the technical aspects but also offering a reflection on the human dimensions of the saga, all with faith that lessons will be learned from what was a horrible situation. We deal with technical facets which are in the public domain; we do not address matters subject to dispute between the various parties.

DEVELOPMENT OF PROBLEMS

A flavour of what happened can be gathered from the following extracts from The Age.

- **22 September 1999:** *A spokesperson for City Link's builders, Transfield Obayashi, said the water issue was an isolated area in the tunnel and the JV partners were confident the construction would be finished by the end of October.*
- **14 October 1999:** *Cracks have appeared in two concrete slabs at the bottom of the City Link Burnley Tunnel.....Joints in the underside of the deepest section of the tunnel, which reaches depths of 60 metres or more, have been leaking...Until yesterday Transurban had maintained the southern link would open by its contracted finishing date of 12 January.*
- **5 November 1999:** "*Testing (of the tunnel floor) in the last week had identified that in two zones....the tunnel floor has lifted unacceptably under that test pressure. Mr Short said," we had not been happy about the integrity so we carried out testing. We found there was a problem*"
- **24 November 1999:** *The* opening *of the Burnley Tunnel could be delayed beyond April..... as result of the need to replace six or seven floor slabs and to anchor a 245m section of the floor at the deepest point of the tunnel.*
- **24 December 1999:** *On Wednesday Transurban said a further five floor slabs had cracked and a further 13 slabs showed weakness.*
- **15 March 2000:** *About 3000 steel rods will be used to anchor two-thirds of the Burnley tunnel's floor to overcome problems....the tunnel was likely to open in September or October.*
- **2 June 2000:** *...the Burnley tunnel is most likely to open in late November...The news comes just two days after TOJV revealed there was a new problem caused by conditions 65 metres underground.*
- **24 September 2000:** *water is still leaking into the tunnel at a rate of 35 litres per second....TOJV last year started remedial work, costing up to $150 million, that required two thirds of the tunnel base to be anchored with 5500 steel rods.*

  With the base now in place grouting is underway and expected to be finished by the end of the month. Last year when problems were at their worst, about 100 litres of water per second were pouring into the tunnel. (About 10 litres per second is considered acceptable).

MANAGEMENT RESPONSE

By November 1999 it was clear to Transfield that the City Link project, in particular the Burnley Tunnel, was in serious difficulties. Transfield management moved Claudio Di Berardino to Melbourne to, for lack of a better phrase, "mount a rescue". Claudio had, amongst others, been the Transfield project director for the Ski Tube in the Snowy's, the Sydney Harbour Tunnel and the Sydney Airport Rail Link. Graeme Peck and I had worked closely with Claudio on aspects of those projects.

Claudio arrived in Melbourne in December 1999, together with his 2IC Bill O'Neil. Within a week Graeme and I were asked to visit the site so as to advise him in respect to what had gone wrong technically, and what was the prognosis. By this time the project design consultants had already designed remedial anchor works for some failed invert slabs, and that work had commenced.

It was clear there were several intertwined issues for us to consider: the key technical reasons for the failures; the status for the rest of the tunnel; and the water pouring into the tunnel with the associated damaging surface settlements which were occurring due to consolidation of Coode Island Silt.

It is understandable, and an understatement to say, that many of the design and construction personnel were in states combining shock and denial. The denial part made it very difficult to create a clear way forward, so Transfield management chose to terminate the design consultancy. The project geotechnical consultants, Golder Associates, remained on board.

On 23 December 1999 Pells Sullivan Meynink Pty Ltd (PSM) was retained by the Contractor to be responsible for the design of all remedial works. The letter to the Transfield Obyashi JV read in part as follows:

> *"It is understood that PSM will work in conjunction with Mr Graeme Peck of Evans and Peck Management and may consult with other specialists in relation to particular matters, such as creep movements in concrete, which are outside our areas of expertise."*

PROJECT BACKGROUND

Geometry and Geology

The tunnels were constructed primarily in Melbourne Mudstone (see Figure 1) except near the portals where basalt flows, mixed rock conditions and clayey soils were encountered.

Melbourne Mudstone comprises interbedded siltstone, sandstone and mudstone and varies from highly weathered to fresh rock. The formation is thinly bedded and is intersected by numerous closely-spaced and variable-width joints and deeply weathered dykes and sills.

Critically, the tunnel alignment passes beneath the Moray Street Gravel (MSG) with a minimum of 10m of moderately weathered or better Melbourne Mudstone over the crown. The MSG is a major saline aquifer, snake-like in plan: it lies beneath the highly compressible, normally consolidated, clays of the Coode Island Silt.

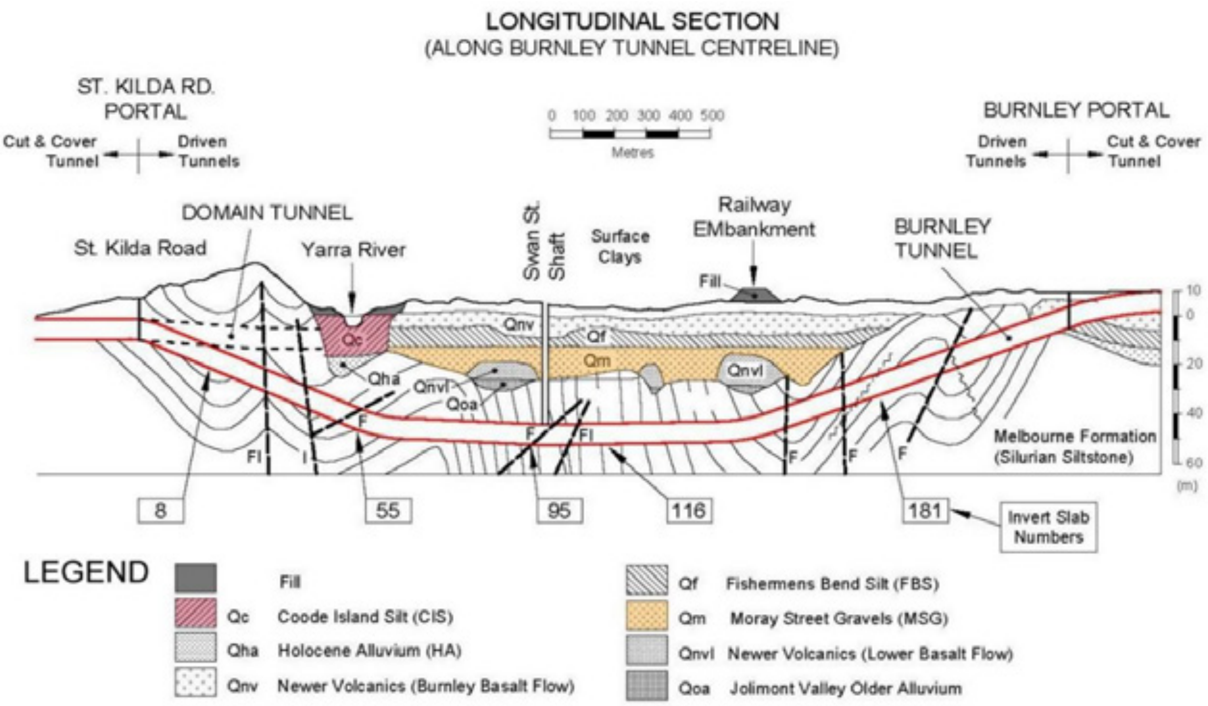

Figure 1: Summary of geology along the Burnley Tunnel

The Burnley tunnel was initially designed to be fully drained and excavation was undertaken on this basis. It was believed that the Melbourne Mudstone would be of such low permeability that significant depressurisation would not occur in the overlying sediments.

Early construction required sinking of the Swan Street shaft near the centre of the tunnel to allow development of two additional headings. Ground freezing was adopted for the upper 40m passing through the alluvium to the base of the MSG. Piezometers showed that as the shaft progressed through the Melbourne Mudstone below the frozen ground section, groundwater drawdown occurred quite rapidly remote from the alignment. It became clear that there was significant hydraulic connection between the Melbourne Mudstone and the overlying MSG.

As the tunnel was extended from the shaft, head drop in the MSG rapidly expanded. Recharge wells were progressively installed to protect affected areas but it became apparent that:

- the MSG was a confined aquifer, with very little recharge;
- unless a substantial system of permanent recharge wells could be established, full length drained tunnels would depressurize the MSG aquifer; and
- the resultant lowering of pore pressures in the overlying Coode Island Silt would produce substantial, and possibly disastrous, consolidation settlement over a wide area, including the extensive commercial areas of South Melbourne (up to 3 km remote from the tunnel), including the Rod Laver tennis complex.

CONVERSION TO AN UNDRAINED ('TANKED') TUNNEL

This led to extensive studies by TOJV to determine viable commercial options for the Burnley tunnel. Graeme Peck, second author of this article and then of Evans & Peck, was one of the experts involved in studies of permanent recharge options. It was concluded that a drained structure was not feasible for most of the tunnel so the design was changed to an undrained ('watertight') tunnel except for 140 meters at the west, and 645 meters at the east ends.

By the time the decision had been made to convert most of the tunnel to be sealed against water pressures up to 60m, the excavation had progressed with a shape assuming the drained solution.

The arch lining for the tanked tunnel was virtually identical to the drained design; a continuous PVC membrane being incorporated between the Primary Lining (rockbolts, sets and shotcrete) and the un-reinforced concrete Secondary Lining.

To reduce the extent of extra excavation required for a true arch invert, a design was developed based on a very thick unreinforced invert slab (see Figure 2).

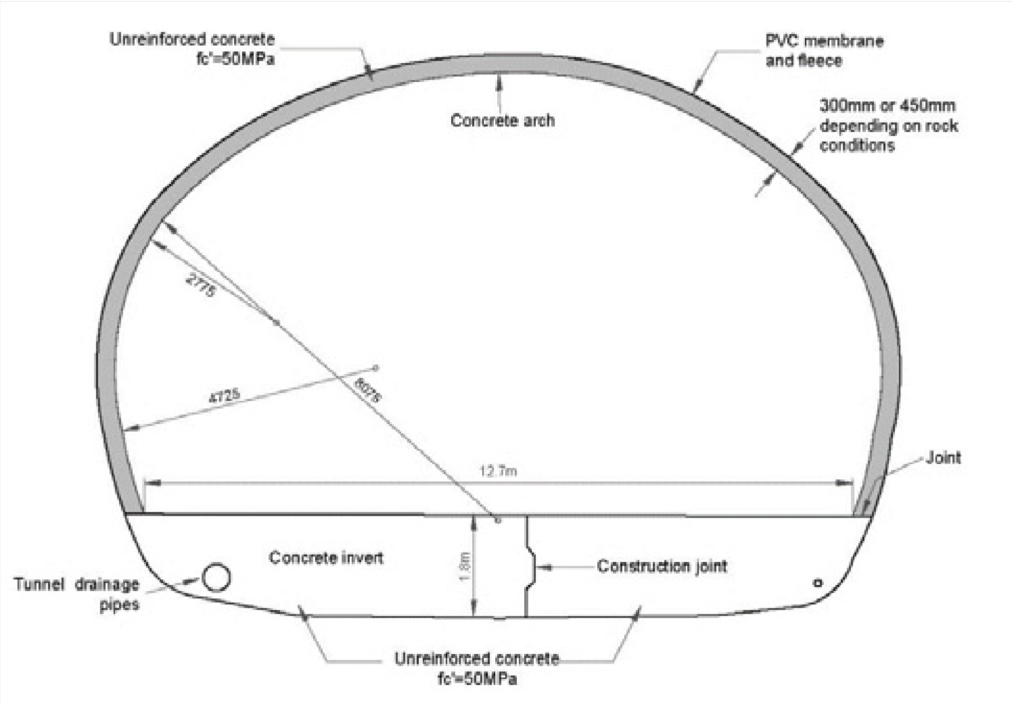

Figure 2: Cross-section through the as-designed permanent lining of Burnley Tunnel

The invert included a longitudinal joint near the centerline as shown in Figure 2, and there are transverse joints at 12m intervals along the invert. Each 12m long invert slab was given a number. The numbering is shown in Figure 1.

Closure of the lining and tanking membrane was achieved on Melbourne Cup day, 6 November, 1998. Immediately prior to closure the total inflow into the tunnel was about 40 litres/sec.

Over the following 10 months the groundwater levels slowly recovered, and during this period various grouting works were undertaken to seal leaks through construction joints, because no membrane tanking is perfect. Total inflows were about 10 to 15 litres/sec. However, the thick floor slabs deflected upwards between about 10mm and 45mm as the groundwater pressures built up.

A significant length of the bitumen road pavement was laid in August 1999 but by October, seepage inflows had increased to about 25 litres/sec, parts of the bitumen pavement had lifted, and the groundwater table recovery had stalled at about 40m. There were serious concerns as to achieving full groundwater recovery, and about the performance of the invert under the maximum serviceability design loading of 600kPa. To this end the groundwater pressures around successive lengths of the tunnel were increased, by injection, to the design pressure. During testing several lengths of the invert failed by upward heaving of up to 200mm, with associated fracturing of the thick, unreinforced concrete invert slabs.

OUR ASSESSMENT

On arrival at the site, Graeme and I inspected the tunnel with Claudio. Then the designers made a presentation of the structural concept of the invert. To us it seemed there was a belief-system about the design. It was not demonstrated by calculation that the design was robust under 600kPa uplift pressure; that deflections would be acceptable; and that fracturing and crushing of the concrete and rock would not occur with associated puncturing of the waterproof membrane. In fact the invert was a flawed design. The structural belief borrowed the concept of a linear arch developed by Evans (1941) for coal mine roof design (see Figures 3 and 4).

The capacity of a linear arch to resist load (uplift pressures in the Burnley case), and the deflections developed in resisting such loading are well known (Pells, Poulos and Best, 1991) as depending on:

- the stiffness of the abutment rock;
- the stiffness of the linear arch material (in this case the concrete);
- extent of opening of any vertical joints, in this case the construction/shrinkage joint in the near-center of the slab; and
- the ability of the linear arch material (concrete) and the abutment rock to resist the concentrated stresses without fracturing and/or crushing.

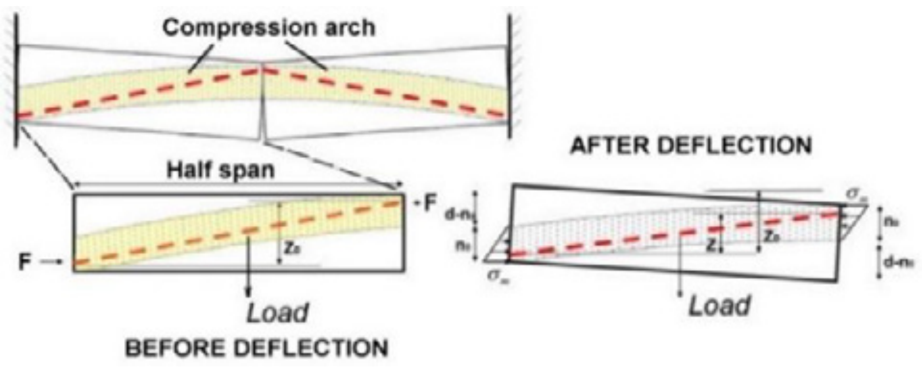

Figure 3 : Linear arch concept of Evans 1941

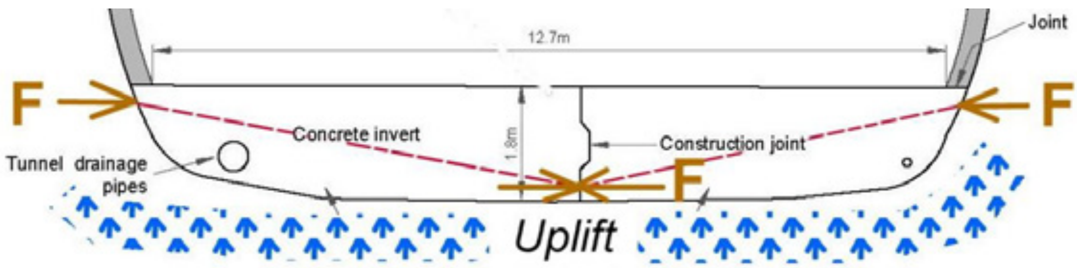

Figure 4: The Burnley invert as a linear arch

STRUCTURAL REMEDIATION

The original project consultants designed a multi-anchor system for remediation of invert slabs near the Swan Street shaft. With some modifications, the multi-anchor design was adopted for slab 55, and for slabs 95 to 116 (see Figure 5).

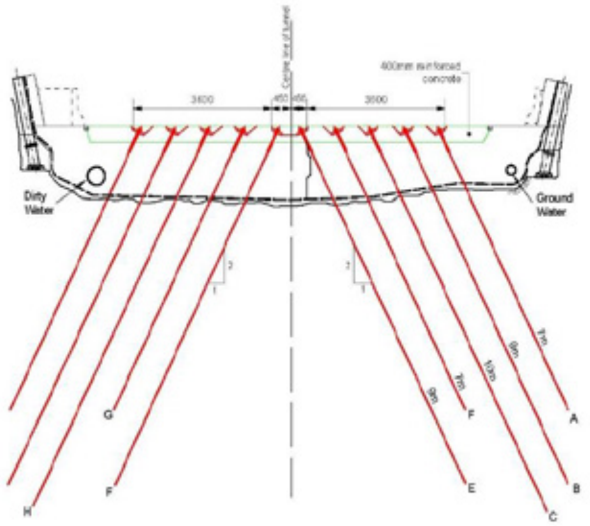

Figure 5: Multi-anchored slabs

Figure 5 shows that these remedial measures comprised:

- trimming 400mm off the existing invert concrete;
- installation of sufficient anchors to resist the uplift pressures (typically 96, nominal 100 tonne working load anchors per 12m long by 12.7m wide invert slab);
- casting of new reinforced concrete capping slabs; and
- stressing of the anchors.

Over the remainder of the tunnel, except for slabs 1 to 12 and 177 to 181 at each end where groundwater pressures were low, remedial work comprised central twin anchors, at average longitudinal spacing of about 1.2m, as shown in Figure 6.

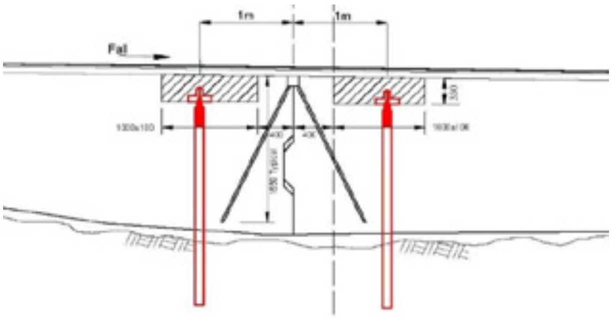

Figure 6: Twin Anchor design

Photograph 1 shows part of the central section of the tunnel during multi-anchor installation. It gives a good idea of the extremely difficult working conditions in the tunnel.

Photograph 1: Multi-anchoring of failed slabs

1990-1999

Photograph 2: VSL stressbar anchors installed after upper part of slabs removed; after stressing that upper part was reinstated with reinforced concrete

Photograph 3: Twin rows of anchors installed either side of the central invert joint in slabs which had not cracked

Photograph 2 shows a patch of completed 46mm diameter VLS stressbar anchors installed after milling away the top 400mm of the original unreinforced invert, and prior to casting the reinforced replacement slab and stressing of the anchors. Photograph 3 shows the twin rows of strengthening anchors installed in slabs which had not cracked.

In total there were about 2500 anchors in the multi-anchored slabs and a further 2700 anchors in the twin-anchored slabs.

The structural remedial measures were completed by August 2000 at which time inflows were about 60litres/sec and there was substantial drawdown of the groundwater system. The task was then to implement a grouting program to reduce inflows to a target value of <10 litres/sec.

STOPPING THE WATER

The 60litres/sec that was entering the tunnel at completion of the structural works was mainly coming through the invert area and from behind the lower sidewalls. Inflows were also entering through transverse joints between arch pours.

To put it mildly it was a difficult grouting project because we were almost working blind and each and every grout hole drilled through the membrane created yet another water path into the tunnel. Fortunately there were excellent mapping records of the geology encountered during tunneling particularly of shear and fracture zones that were the major water paths through the folded siltstones. The logging had been done by the Joint Venture's geotechnical group under Bruce Hutchinson, including geologists from Golder Associates.

It was decided that the only way the grouting objective (of <10litres/sec) could be met was to provide multiple lines of defense. The strategy therefore comprised

- chemical and micro-fine cement grouting to form circumferential cut-off rings at intervals along the tunnel to cut-off flow along the tunnel between rock and membrane;
- micro-fine and ultra-fine cement grouting of highly permeable features in the rock;
- chemical grouting of water paths at the contact between the rock and the original primary shotcrete and steel set support, and between membrane and concrete; and
- ordinary Portland cement grouting of any voids beneath the invert (i.e. on the rock side of the invert membrane) arising out of uplift movements of the invert slabs.

The work took 5 months, commencing in mid-July 2000. Throughout this period it was very difficult to measure whether we were being successful because water introduced into the tunnel for drilling, and other construction processes, made it impossible to measure the natural inflows (see Figure 7). We had to stick to the logical plan even when it seemed not to be working.

By mid-December 2000, rock mass cement grouting of 5604 holes had been completed, and 6482 holes had been drilled and grouted with polyurethane and acrylate grouts. The cement grouting was performed by National Contracting/VSL and the chemical grouting by Eptec Pty Ltd.

By the 11th November 2000 all tunnel electrical and mechanical facilities had been tested and the tunnel was ready for traffic.

Between 14 and 16 November, final wash-down occurred with discharge from the tunnel peaking at 150 litres/sec. We held our collective breaths, and a few days later the inflow was measured at 7.9 litres/sec. Over the following months the groundwater table recovered to about 55m head and inflows were about 9.4 litres/sec.

The tunnel opened on 22 December 2000, giving Melbourne's traffic a Christmas present.

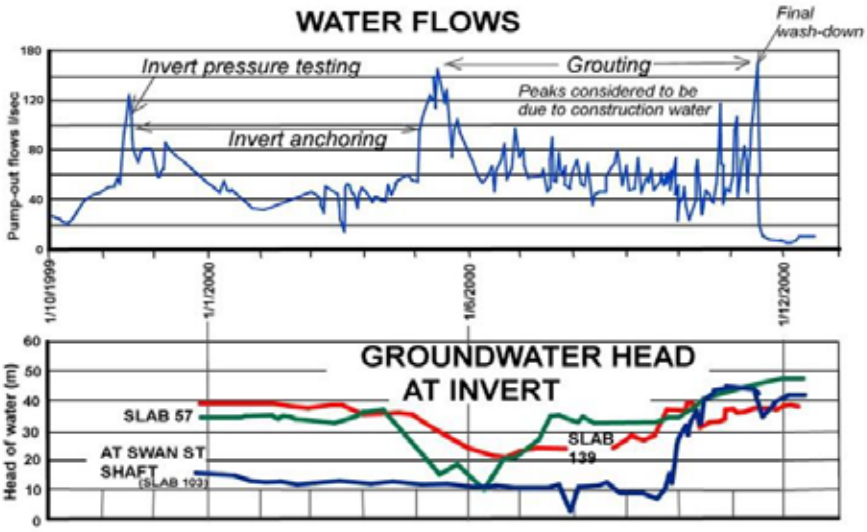

Figure 7: Inflows and Groundwater Pressures

THE PEOPLE

Most of this article deals with technical issues associated with the remedial works. Too often the human side of such project mishaps is ignored.

At the time, Graeme, I and others involved in the remediation felt badly for colleagues associated the original design, for whom so much had gone wrong. In particular we want to mention Alf Neilson, who a few years before was the key member of the Wargon Chapman group who conceived the idea of the Sydney Harbour Tunnel (SHT). Alf led the SHT design team and was director for the Burnley Tunnel design team. To gain an idea of the stress applied to Alf, and others, we note the following entry in The Age on 25 October 1999:

- **25 October 1999**: *The builder of the City Link has launched legal action over what it says were serious faults in the designs of two massive tunnels of the tollway. The claims are issues in a writ issued against a consortium of engineers made up of Hyder Consulting, CMPS&F Pty Ltd and AWC Victoria Pty Ltd and three executives. The writ was issued in June.*

At the time, and to this day, Graeme, I and many others considered the suing of individuals (the three executives) to be contemptible, unjust and cruel. It is companies that are insured; designs are never the actual responsibility of an Individual, and individuals should not become personal legal targets.

At about the peak of the drama Alf Neilson died of a heart attack one Saturday morning, whilst attending kids' soccer.

Alf Neilson - interviewed in relation to the Sydney Harbour Tunnel, 1989

Turning to the matter of construction we were, and still are, in awe of the extraordinary work by construction personnel of the TOJV during the remedial works. In mid-1999 they had almost got the tunnel to opening day; the champagne was in the fridge. Then the wheels fell off. But they did not waver. Naming individuals is always invidious, but when the Melbourne winter winds jetted through the shambles in the tunnel; when it was cold, wet, dark and depressing, the efforts and dogged enthusiasm of Ross Herbert, Ray Verratti, Matthew Gault and Gary Giffioen were almost unbelievable.

DENOUEMENT

It took a year, and well over $100 million, to recover the project. Many key people were involved. We can only name the ones we worked with:

- Associate Prof. Peter Ansourian of University Sydney; independent reviewer of PSM;
- Professor Ian Gilbert UNSW; advice on concrete creep;
- Dr Mike Coulthard; specialist advice to PSM in regard to UDEC analyses;
- Neil Benson of Golders, site geology;
- Dr's Mothersille and Weerasinghe of Geoserve Global; anchor design;
- Ed Taylor and Malcolm Short of TOJV;
- Bill Meynink, Derek Anderson, Mark Eggers and Garry Mostyn of PSM;
- our friend whom we still miss, the late Enrico Piccioli of Eptek; and
- at the head, Claudio Di Berardino and Bill O'Neil.

The Sydney Morning Herald records:

> *In 2001, the same year the tunnel finally opened to traffic, Transurban and Transfield Obayashi settled a $153 million damages claim over the costs of repairing the tunnel.*

But nature was not finished with the Burnley tunnel and on 19 February 2001 the southern sidewall of the tunnel failed at about the deepest part. Water gushed into the operating facility. The repair of that failure and the subsequent need for strengthening the join between the sidewalls and invert is another drama for someone else to tell.

OUR LESSON

Our lesson from the Burnley tunnel failure is, again, that engineering is not a belief system; engineering is a step by step process as set out by Descartes some 380 years ago, wherein we set our faith on data, logic and calculations using Newtonian physics. As Descartes said, better than anyone since:

> *"I thought the following four [rules] would be enough, provided that I made a firm and constant resolution not to fail even once in the observance of them.*
>
> - *The first was never to accept anything as true if I had not evident knowledge of its being so; that is, carefully to avoid precipitancy and prejudice, and to embrace in my judgment only what presented itself to my mind so clearly and distinctly that I had no occasion to doubt it.*
> - *The second, to divide each problem I examined into as many parts as was feasible, and as was requisite for its better solution.*
> - *The third, to direct my thoughts in an orderly way; beginning with the simplest objects, those most apt to be known, and ascending little by little, in steps as it were, to the knowledge of the most complex; and establishing an order in thought even when the objects had no natural priority one to another.*
> - *And the last, to make throughout such complete enumerations and such general surveys that I might be sure of leaving nothing out.''*

Rene Descartes, Discours de la Méthode, 1637

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DR TONY PHILLIPS CHAIR 1996 – 97

> Firmer foundations were required to allow the Society's already sound structure to blossom and offer enhanced benefits to members

The mid-'90s were turbulent times for the AGS. I think it is fair to say that the various chapters around the country were very active, as they should have been, putting on technical talks and events, and acting as a meeting place for geomechanics professionals in the broadest sense. On the face of it everything was going well, but at the national level things were less rosy. AGS had always been a technical society within the Institution of Engineers Australia (IEAust) – a special interest group, not sufficiently large or important enough to be a separate college. It was frequently held up by IEAust as an example of how its technical societies should run, with regular meetings, involvement on Australian Standards drafting committees, a strong national membership and international recognition and involvement. It seems amazing, therefore, that at the same time we had no knowledge of our financial situation and had to go cap in hand to the Civil College for approval of any significant initiative. One way and another we felt caught in a sort of a straight-jacket which was inhibiting our development.

The graph in Figure 1 below, taken from Harry Poulos' presentation "The Australasian Region & the International Society", to be found on the AGS website, suggests an additional cause for concern. Membership of the AGS carried with it automatic membership of one of the International Societies. The graph shows a 20% loss of Australian members of ISSMFE (which changed its name to ISSMGE in 1997) between 1991 and 1996, which may reflect a similar drop in AGS membership. Unfortunately, no membership data seems to be available in the Society's archives.

Nationally we were in the doldrums. Much of my time as chairman was spent trying to recover this situation. It was decided that we had to prepare for the worst – total separation of AGS from IEAust. This was considered to be an undesirable outcome, but nonetheless a possibility, and took us into uncharted waters. We proceeded one step at a time. It was realised that if we became an independent organisation, we would have to replace the protective umbrella that IEAust had always given us, with something else, including a corporate structure, adequate insurance cover for office bearers and financial security. The only way that we could imagine doing this was to get ourselves into a situation where we could become an incorporated body, having appropriate protection under the law.

Much effort went into developing a robust AGS Constitution, to replace the much looser statutes which had existed to date. Legal advice was sought, in order to ensure we had covered potential legal consequences. It was not submitted to the members until late 1997, and still had to be accepted by ballot in all Chapters. This finally occurred, and I am glad to see it remains essentially unchanged to this day.

The constitution was the first step towards the AGS becoming independent, but so was money. With no historical financial information, we had to work out for ourselves what the Society actually cost to run. This quickly led us to the conclusion that membership fees were nothing like adequate to cover costs.

Perhaps coincidentally, IEAust published a document in late 1996 entitled *"Technical Societies of The Institution of Engineers Australia Guidelines and Regulations."* This document required technical societies to share the responsibility for funding their activities with IEAust. This was a totally new concept from our point of view.

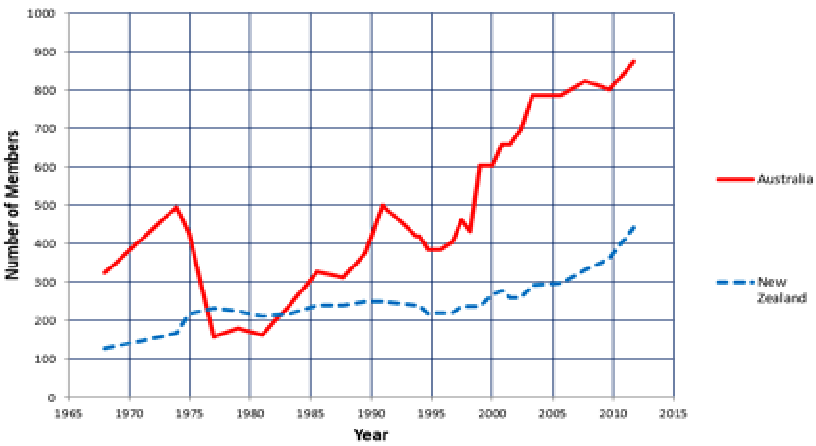

Figure 1: Historical ISSMFE membership data, showing a decline in the period 1990-1995

Fortunately, we were well on the way to making the changes necessary to become independent from IEAust, if necessary, so we were able to enter into negotiations having a good idea of where we stood.

In order to generate an income, it was decided to increase members' fees by something in excess of 200%; require non-members of IEAust to pay more than members; and to require local Chapters to run seminars, or similar, at least once a year to create their own income stream. The fee increase caused some on the National Committee to warn about the imminent demise of the Society, but ironically the opposite happened. Whether or not people subconsciously associated an increased fee with a better service I do not know, but I think that is what they got. Looking again at Figure 1 it would appear that by 1997 there was an upward trend in membership numbers of ISSMGE and that it has, to a large extent, continued ever since.

On the technical side of things during this period:

- a Newcastle based committee organised a conference on the *Engineering Geology of the Newcastle-Gosford Region* (Feb 1996);
- a *National Symposium on the Use of Re-cycled Materials in Engineering Construction* (May 1996) was held in Sydney;
- the *Seventh ANZ Conference on Geomechanics* (July 1996) was held in Adelaide;
- the *First ANZ Conference on Environmental Geomechanics* (1997) was held in Melbourne.

The Adelaide Conference was very well received and notable for its special session on Education in Geomechanics. It was also memorable, on account of a story one well known and respected professor had to tell on his arrival at the conference. If my memory serves me well, he was driving to Adelaide and getting low on petrol early one morning. He pulled into a servo, somewhere in the middle of nowhere, to find it closed. However, he noticed that the bowser had the facility to insert a credit card, a novel concept at the time. Insert his card he did, and then pushed every button he could find, wiggled every lever and when nothing happened, gave it an almighty kick for good measure, retrieved his card, got back into his car and set off.......only to find that the bowser was following him down the road! Yes, he had forgotten to pull the nozzle out of his car. This apparently amused a local out for a morning stroll, who had watched the whole thing. I can't remember what happened after that, but it was a good enough tale to be told more than once over a beer in the next few days. No doubt the obvious explanation was a controlled test which showed the bowser foundation to be totally inadequate.

In 1996 Dave Stapleton was awarded the Jaeger medal for his paper entitled *"Keeping the 'Geo'- Why and How"* and Mark Randolph was selected to give the EH Davis Memorial Lecture in 1997 for his work on offshore foundations.

Australian Geomechanics (News) continued to be published twice a year under the direction of an editorial committee based in Queensland (Keith Wallace, Bevan Boyce, and Pat Wilson) until the December 1996 edition. They were followed in 1997 by a Newcastle based committee under the direction of Stephen Fityus. Throughout this period copy was assembled and published under the watchful eye of Patrick MacGregor.

All this, coupled with several other conferences in the planning stage, suggests an active and energetic society which had kept going despite the problems that the society was wrestling with at the top level.

On the 30 July 1997, the Thredbo Landslide occurred, with the loss of 18 lives. It was an awful tragedy which led to various investigations, court claims and a coroner's report which concluded that

> *"The geotechnical community needs to evaluate the way it conducts its investigations to ensure that investigations be undertaken having regard to the potential effect of instability on human life and the risk of loss of life or injury."*

Figure 2: Aerial view of Thredbo landslide

Apart from the immediate consequences for individuals and property, this was a catalyst that led to renewed focus on landslide risk management methods. Ultimately, driven by Robin Fell and Bruce Walker, *Landslide Risk Management Concepts and Guidelines* were published in March 2000 and, much later in 2007, the *National Disaster Mitigation Landslide Risk Management Guidelines* were published in Australian Geomechanics in March 2007.

1990–1999

DR CHRIS HABERFIELD CHAIR 1998–99

The AGS had its own Renaissance in the mid to late 1990s, providing the groundwork for what the society is today.

During the mid to late 1990s the AGS went through a particularly tumultuous period with many changes in how the AGS did its day to day activities. A major driving force behind these changes was the IEAust review of societies which resulted in new guidelines and funding arrangements.

The most important of these changes were:

- We went from a historical position (through no fault of our own) of having little idea about our finances and almost no control over our budget to having complete control. We basically went from playing with monopoly money to real $, which meant greater financial responsibility. At that time the annual turnover of the National Committee was in excess of $100,000 with that of local chapters generally less than $10,000.
- A substantial increase in the yearly membership subscriptions which was required to maintain the viability of the AGS following reduction in support from the IEAust. There were concerns that this would negatively impact on our membership, but the opposite occurred with membership numbers increasing to about 1000 in 1998.
- A new constitution, primarily due to the efforts of Tony Phillips.
- A new Heads of Agreement between the AGS, AusIMM and IEAust, which set out the responsibilities of each organisation promoting closer relationships and greater collaboration.
- AGS Chapters were provided with their own budgets and funding from the AGS National Committee in addition to local support from IEAust. By the middle of 1999, our local chapters were significantly less reliant on funds and support from the IEAust divisional offices, providing them with independence and a level of freedom they had not previously experienced.
- A desire to increase our financial reserves by running seminars and conferences to be able to provide improved services and support for AGS members and to underwrite and profit from our own conferences rather than relying on IEAust. By the end of 1998 we had in excess of $30,000 in reserve, which set us up well for the future.

The current AGS membership has greatly benefited from these changes and it is pleasing to see that we are now financially in a position to not only support a regular supply of overseas speakers (including Rankin and Terzaghi lecturers amongst others), local conferences (including the ANZ and Young Geotechnical Professional conferences) but also major international conferences.

It was also during this period that the AGS launched its own website – thanks to the work of Mark Randolph and others, and we changed the format of Australian Geomechanics with a view to it being both a news journal and a technical publication. A greater emphasis was placed on attracting regular contributions from members and offsetting the cost of production by relying on advertising. It is now very pleasing to see the quality of the journal and its wide readership.

The Thredbo landslip in 1997 was a particularly dark day for Australia, however it was pleasing to see the response of the AGS to this tragedy. The AGS formed a task force of experts headed by Robin Fell with a view of forming guidelines and recommendations for hillside construction. This was a huge task and the task force worked tirelessly to complete this work in a very short period. The guidelines that were produced and have since been revised, and will undoubtedly be subject to further revisions, are widely used and are a testament to what the AGS can achieve when we work together.

During 1998, the IEAust unilaterally decided to develop a specific area of practice within NPER for civil engineers in the area of suburban geotechnics. The AGS had previously opposed this move but found itself assisting IEAust in this process. This process of registration continues to role on today with what will soon be registration for geotechnical engineers. Hopefully it will not get to the ridiculous position of us having to register in every state!!!!

Other concerns at the time revolved around the engagement of our young geotechnical professionals with the AGS and the dwindling opportunities to undertake masters level coursework courses in Australia. Significant emphasis was placed on what the AGS could do for its younger members, something that we still grapple with today.

In the end, like any society, you can only hope to benefit from it if you are involved – so to all our young AGS members out there – get involved, there is much to benefit.

By the end of my tenure as Chair, I felt that as a society we had grown and matured with our independence from our sponsoring bodies, and that our relationship with the IEAust in particular had become more harmonious.

The position we found ourselves in could in part be attributed to the excellent administrative support we received from Val Lee, a willingness by the then IEAust management to let us do things our way, and our financial independence which meant we were not hamstrung by the meagre funds from our sponsors. At that time the AGS went about its business with very little interference from IEAust or AusIMM. However, it had only been a short time since this was not the case, and there remained the distinct possibility that changes in key personnel within IEAust and/or organisational restructuring could see us return to the bad old days. This prompted the AGS to pursue incorporation.

My many years on the National Committee were both challenging and enjoyable. I look back on those years with fondness and am very proud of the society we have become. I have seen the AGS go from strength to strength and to mature like a fine red wine. It is particularly pleasing to me to see the growth in the number of national and international speakers at local chapter meetings, the quality of the AGS journal and the success and quality of the many conferences we now run and underwrite.

FROM THE CHAIRMAN'S DESK

Welcome to the first edition of our new look Australian Geomechanics. As part of our push to improve service and value for money to our members we have decided to publish the journal four times a year, and in doing so have extracted a promise from our current editor, Garry Mostyn that editions will get out on time. However, to make Garry's job easier it will be necessary for everyone to prepare their contributions in a timely manner. The success of the journal depends largely on the input from you, its members. Submissions are not restricted to technical papers. Garry would dearly love to be flooded with short technical submissions on almost any geotechnical topic. Such short contributions need only be half a page in length and cover such things as case studies, a recent interesting project or part there of, opinions on current issues or review of a recent book, standard, conference etc.

The journal is a very easy way to communicate with our membership at large, but very few of us use it. From my experience, most geotechnical professionals have quite strong views on at least a dozen technical matters. These views are freely expressed to a very small audience over a not so quiet drink, but rarely get into print. Lets all try to find 30 minutes over the next year to put some of our ideas down on paper and get them into Garry. With your help, Australian Geomechanics will be able to achieve its full potential.

Before leaving the issue of Australian Geomechanics, I would like to sincerely thank our last editor, Steve Fityus and his helpers for their fantastic efforts in producing Australian Geomechanics over the last two years. For those of you who don't know, Steve is a postgraduate student at the University of Newcastle, currently completing his PhD. A couple of years ago, the AGS was having difficulty finding someone to take over the editorship of the journal. The Newcastle Chapter came to our rescue, and Steve kindly but perhaps foolishly agreed to take on the mantle of editor, knowing full well that it would hinder progress towards his PhD. Thank you for your efforts and congratulations on a fantastic job.

I have been receiving a lot of correspondence lately from the IEAust concerning continuing professional development or CPD. One of our main functions is to provide CPD to our members, and in doing so we provide a very important service for the IEAust. This CPD is in the form of local technical meetings and seminars, Australian Geomechanics, local, national and international conferences, special initiatives like the Hillside task force and production of publications on the engineering geology of specific areas such as around Sydney, Melbourne and the Hunter Valley. The IEAust has recently become aware that they are not funding these activities to an appropriate level, and are therefore gearing up to allocate real funds to CPD. Extra funds should soon become available at local level. It is important that we use these funds wisely, and provide quality CPD service to our membership.

Over the last year or so, a number of AGS members have expressed the opinion that the AGS is akin to an old boys club, where if you are on the outer, nobody really cares or makes an effort to invite you in. This is particularly apparent at local chapter meetings, where little effort appears to be made to make new members or even old but irregularly attending members feel welcome. The same could be said of our local and National Committees and our local and national conferences. I would urge all those members who feel that they are on the outer to keep trying, and all those who are in the inner to make a conscious effort to open their ranks and make others feel welcome. If anyone has a particular concern, please feel free to contact me.

Chris Haberfield
Chairman

Vignette from *Australian Geomechanics* September 1998

THE THREDBO LANDSLIDE

Laurie graduated in Civil Engineering from Sydney University in 1968 and then in 1975 completed a PhD in Soil Mechanics studying under Prof. Harry Poulos AM. His employment has always been in consulting engineering but he has also embraced senior management roles. In 1969, with partner Peter Stone, Laurie established a specialist geotechnical consulting firm. He fully retired in 2013.

During a working career covering both geotechnical and rock mechanics aspects, Laurie remained fully conversant with all technical aspects. He was often engaged as a technical expert and authored (or co-authored) many technical publications.

DR LAURIE DE AMBROSIS

THE EVENT

On the morning of 31 July 1997, as per usual for a working week day, I was awoken by my clock radio just in time to hear the 6.00 am version of the news on ABC radio station 702. I can remember that it didn't immediately "sink in" but I soon became alerted to the fact that on the previous night, that is, on the evening of Wednesday July 30 at about 11.30pm, there had been a landslide at Thredbo in the Snowy Mountains of NSW which had caused the collapse of two lodges and that it was expected many lives had been lost.

I didn't know it then but the 2 lodges that had been impacted were Carinya Lodge, in which the sole occupant at the time had been killed, and Bimbadeen Lodge in which 17 people lost their lives. There was a single survivor from the tragedy, Stuart Diver, who was resident in Bimdabeen at the time of its collapse. The landslide occurred in an area of quite deep fill along a section of the Alpine Way where it passed along the steep mountain slope above the lodges of the village (refer to Figure 1).

I first inspected the landslide site on 1 August 1997 at which time it was apparent that a significant quantity of water had been involved in the failure because the failed soil was both very wet and had traversed a great distance downhill in the form of a flow slide. The mass of moving soil initially cascaded onto the uphill side of the Carinya Lodge and caused it to collapse. From there, it progressed further downhill, across Bobuck Lane and, in turn, into Bimbadeen lodge causing it to collapse, before coming to rest just above further lodges located at the toe of the slope. Subsequent investigation showed that the landslide had occurred in two separate stages viz:-

- an initial stage which moved from the top, west corner of the landslide (the corner directly above Schuss Lodge in Figure 1) in a direction towards Munjarra Lodge at its toe. That is, in a direction across the slope. It caused the destruction of the east end of Carinya Lodge. I believe from reports by people of noises commensurate with those of landslide movement, up to some 24 hrs before the catastrophic event, that the initial movement of this stage may well have been slow and intermittent.
- the second stage was then triggered by the first as a result of it removing buttressing material from the toe of the remaining embankment. This, in turn, caused material on the east side of the embankment to move directly downhill. In a compounding effect, this latter material fell onto the saturated soil from the stage 1 movement thus facilitating sliding of the overall mass by creating a layer of liquefied material at its base.

Figure 1: View of landslide

- It was apparent that the entire mass from the second stage failure became very mobile and progressed a great distance downhill destroying all in its path before coming to rest at the toe of the slope.

THE COMMUNITY RESPONSE

The landslide set in train an immediate rescue response including the arrival on site of the fire brigade, police and various emergency services and rescue organisations aided by professional advisors which, because of the nature of the failure, included many eminent professional geotechnical engineers and geologists. I was one of the geotechnical consultants called to site.

At the time of my arrival, many of the bodies of the deceased still had to be recovered from beneath the debris and, indeed, Stuart Diver was still buried under the collapsed debris. He was eventually rescued largely via the efforts of mine rescue personnel who had located and then extracted him by "tunnelling" along the interface between the building debris and soil slope. I can still remember very clearly that Saturday afternoon when virtually all on site briefly stopped whatever work was being done and clapped and cheered once we heard that Stuart Diver had been rescued, that he was alive and appeared not to be badly injured.

MY INVOLVEMENT

I had been engaged to go to Thredbo by the National Parkes and Wildlife Service of NSW (NPWS) following a request of that department by Mr Peter McClellan QC (now The Honourable Peter McClellan AM QC), to engage the services of an expert geotechnical engineer to provide expert professional geotechnical advice for what he and the NPWS could foresee would be a lengthy and detailed coronial inquiry to be followed possibly also by later legal actions.

I received the NPWS instructions on Thursday 31 July 1997 and without delay made my way to the NPWS office in Jindabyne from where I first went to Thredbo. I was then to spend a large amount of time in Thredbo, usually days at a time, on and off, over a period spanning from that first day until well into the construction of the remedial works on the Alpine Way above the village. In between, I also attended the Coronial Inquiry and the later commercial civil litigation.

THE GEOTECHNICAL INVESTIGATION

Immediately following the landslide, the State Coroner, Mr Derrick Hand, inspected the site and soon afterwards arranged to appoint a geotechnical consultant to assist him in his work. That consultant, Mr. Tim Sullivan of Pells Sullivan Meynick Pty Ltd (PSM), came onto site on 4 August 1997. Mr Phillip Pells from that office had been on site on 3 August 1997.

A decision was then made that the site within the immediate environs of the landslide, which had a police cordon around it to restrict public access, was to be investigated exclusively by PSM with the results made available to all other interested parties at a later time. This latter group would subsequently grow to include many specialist geotechnical consultants who were appointed to advise many of the other interested parties.

By that time I had received instructions to prepare a report on the cause of the landslide. Separately, I was also instructed to provide advice to NPWS on the stability of the remaining sections of the Alpine Way where it traversed above the village, and also to investigate the stability conditions within the village and the slopes above the village. In regard to the landslide site, whilst excluded from direct involvement, I and other colleagues actively participated by way of suggestions to Mr Sullivan for his investigation.

In parallel with Mr Sullivan's investigation I began my investigation of the stability of the Alpine Way concentrating initially on that section that traversed above the village. This included not only the embankment fills and cut batters of the roadway but also the slopes above and below it. In this work I was very capably assisted by Mr Greg Kotze, a very competent and experienced engineering geologist from our firm along with other professionals from the firm.

This latter part of my work at Thredbo will not be discussed in this paper other than to record that the work involved putting down many subsurface investigation holes along the Alpine Way in that section where it passed above the village including alongside the area rendered off-limits by the police cordon and the mapping of the slopes above and below the Alpine Way including above and below the landslide site.

The work was done in great detail and provided very specific knowledge of the subsurface conditions including comprehensive information on groundwater levels and seepage patterns both surface and subsurface, particularly in relation to seasonal cyclic variations. This information ultimately was made available to all parties involved with the investigation of the landslide. However, as it became available, the information was used by my team for the dual purposes of a) providing an early warning system for any slope instability that might have threatened the safety of lodges, particularly in that critical period immediately after the landslide, and b) for later use in the most important task of determining the cause of the landslide. As can be appreciated this latter task required an accurate, representative geotechnical model of the landslide site and of the groundwater conditions beneath it. The information also was used for the later geotechnical design for the reconstruction of the Alpine Way above the village which I was able to start once control of the landslide site was handed back to the NPWS on 2 February 1998.

THE CORONIAL INQUIRY

The results of the investigation carried out by Mr Tim Sullivan were made available to all consultants in two separate reports issued in March and May 1998. These reports were then followed by Mr Sullivan's "Analysis of the Thredbo Landslide" report in July 1998. This report contained Mr Sullivan's conclusion as to what he considered to be the most likely cause of the landslide. The Coronial Inquest commenced its hearings in August 1998.

The first issues addressed in the Inquest were those relating to the rescue operations etc. However, as the hearing progressed and the issue of the cause of the landslide approached, the Coroner became concerned with the many technical experts likely to be called and sought to confine the areas of technical expert evidence to expedite proceedings. In this regard Counsel assisting had proposed a Convocation of Experts with the intention of identifying areas of agreement and isolating areas of disagreement. This Convocation took place in April 1998 before the Honourable Terence Cole AO RFD QC.

It may not come as a surprise to be advised that at the conclusion of the Convocation there still remained areas of some disagreement. The Convocation agreed that the **landslide had been the result of an abnormal increase in** the groundwater pressure in the embankment fill but there was disagreement as to the source of the groundwater that had been the initial cause or "trigger' of the landslide. Two possible sources had been identified viz:-

a) infiltration from seepage flowing in a drainage trench at the base of a new retaining wall constructed on the uphill side of the Alpine Way at the top of the road embankment (refer to Figure 1 where the wall can be seen at the top of the photograph), and

b) a leaking joint in a water main located at top, west side corner of the road embankment (refer to Figures 1 & 2).

The retaining wall had been constructed by the NPWS in the period February to March 1997 for the dual purposes of improving the line of sight along the roadway and to relieve traffic congestion associated with the parking area above Schuss lodge. However, the wall also served to collect seepage water from a spring located above Schuss lodge and to direct it eastwards for discharge into a stormwater culvert uphill of Munjarra Lodge. The wall incorporated a somewhat unique feature for drainage in that all seepage water including that collected from the spring was directed via a basement layer of gravel into a larger 225mm diameter slotted drain which passed along the front of the wall in a trench covered over by the bitumen road pavement (refer to Figure 3). In the area above the landslide this trench had been excavated in the extremely weathered residual bedrock which underlay the roadway. It is that element of water flowing in the trench that was lost by infiltration into the basement layers of the extremely weathered bedrock that had been postulated as the source of the additional groundwater that triggered the landslide.

The water main comprised an assembly of approximately 4.0 m long X 100mm (4 inch) diameter asbestos cement (AC) pipes joined together by water tight couplings known as "supertite" couplings. These couplings were push together socket and spigot couplings with a rubber ring joint positioned in a purpose made groove on the inside of the socket so as to cause the rubber ring to fit firmly between the socket and the machined end of the pipe as it was inserted into the coupling. The pipe end had a witness mark to ensure correct insertion for water tightness.

Figure 2: Broken AC pipe in landslide scarp

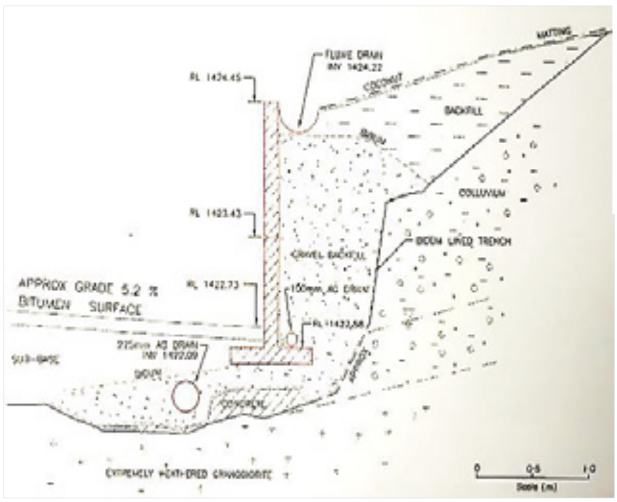

Figure 3: Retaining wall details

1990-1999

The water main had been constructed in April-May 1984 and supplied lodges located along the Alpine Way. From water supply tanks located further to the west, it traversed along the roadway on its downhill side, until just past the east end of the car park behind Schuss Lodge. From there it made an approximate 90 degree turn downhill towards Bobuck Lane. Excavation carried out on 3 August 1997 by me, showed that in the region of the Schuss car park, the pipeline was buried about 1.0m below the ground surface and that it was located in fill which at the east edge was in excess of 4.0m depth. The excavation also revealed that at a depth just below the pipeline, the fill contained some quite large inclusions of deleterious material comprising in part buried builder's rubbish, old tree branches and other buried vegetation.

At the time of the landslide the broken end of the pipe lay exposed in the side of the slip scarp (refer to Figure 3). However, that part of the pipeline from the broken end to where it had turned to pass downhill and for a distance beyond, where it had been located in the embankment fill, was missing. It had been demolished by the landslide and subsequently removed from site with the other debris. It was not able to be recovered.

Investigations principally by Mr Sullivan had revealed that prior to any gross movement of the landslide mass, there had been significant leakage from the water main and that a large amount of water had entered into the embankment fill from this source. Exhumation of the pipeline carried out on 3 August by both myself initially and then continued by Mr Pells of PSM showed that the first and second of the couplings back from the slip scarp had pulled apart. The first joint, which I will refer to as Joint 1, was found in a position where significant leakage had occurred and the second where water tightness was likely compromised. It was apparent that the pipes in the trench had been laid on a bed comprising a mixture of sand and gravel. However, the back fill around Joint 1 contained what I described at the time as "washed gravel" – that is, surrounded by bedding material absent the fines. It was quite apparent that Joint 1 had been leaking and that the fines in the gravel both beneath and on the downhill side of the joint had been washed away (refer to Figure 4).

On the surface of the car park and in line with the water main above this joint, "pipe" holes could be seen to exist. It was apparent from the evidence of residual flow marks on the car park surface that water had exited from the leaking joint and had flowed via the pipe holes onto and across the car park surface. This water could only have emerged from the water main before it had ruptured and therefore preceded the gross movement phase of the landslide. The direction of flow had been towards the slip scarp. It was quite apparent that water from this leaking pipe had been a significant factor in the landslide.

Figure 4: Joint 1 – as exposed

CONTESTED MECHANISMS FOR THE INITIATION OF FAILURE

Whilst there had been general agreement to the above, there existed disagreement on the cause of the initial movement that had caused the large-scale leakage at Joint 1. I formed the view that the gross leakage described above had been preceded by an extended period of less intense leakage from this same joint (and possibly also other joints) and that development of this earlier, less intense leakage had been caused by a gradual joint(s) "pull-apart", predominantly due to soil creep movement of the fill material in which the pipeline was situated. I could easily reconcile that soil creep was an active factor particularly given the loose nature of the fill, the very steep angle of the batters and the non-homogeneous composition of the fill including such deleterious inclusions as described previously.

A slow leak from the water main would not be expected to have caused an immediate instability situation within the embankment and in fact could largely have occurred without initially being noticed. However, gradually the seepage of water into the fill can be expected to have exacerbated the situation in regard to both the creep and settlement components of movement.

This in turn can be expected to have increased the amount of pull out at the joint(s) with the result that leakage would have gradually increased. Eventually this process would lead to the situation where the gross leakage described above could occur.

Creep movement of the fill batters and settlement of fill areas were clearly in evidence at the site both from observation of surface phenomena and from the readings of the slope inclinometers installed in our investigation for NPWS. The existence of these phenomena was not disputed although there was debate concerning the magnitude of past movement that may have occurred. I was very comfortable with the order of movement necessary to have caused the observed pull out and that it was commensurate with the order of movement likely from the resolved components of embankment creep and settlement.

Exhumation of the pipe also revealed what I believe was compelling evidence of gradual pull out of the pipe spigot from the coupling housing at Joint 1. When dismantled each of the pipe spigots contained a black ring mark where the rubber ring seal had been pressed tight against it by the socket housing. For those joints furthest from the landslide scarp, this rubber mark was relatively thin, commensurate with the width of the rubber ring. Further, the black ring existed at a distance from the end of the pipe in keeping with where the witness mark had determined the correct depth of insertion. However, at Joint 1, the rubber ring mark on the spigot was quite thick and spread back across the spigot surface from where it had been initially set to a location well away of that initial setting and to where leakage could be expected (refer to Figure 5).

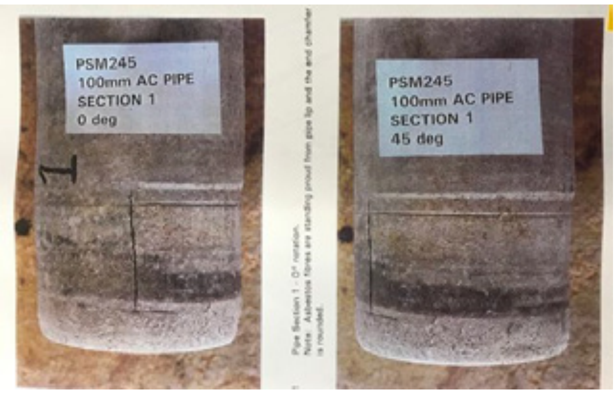

Figure 5: Joint 1 extra wide black mark

The resident time required for the rubber ring to form an effective permanent mark on the pipe spigot is not known so that the time it took for the pipe to become marked in the manner exposed is not known. However, in conjunction with the extra wide rubber ring mark, the pipe spigot also had a groove cut into one side and a complementary flat spot on the opposite end indicating rubbing of the spigot against the collar and inside wall of the socket (refer to Figure 6). These markings were in an approximate horizontal plane indicating lateral movement of the assembly in a downhill direction commensurate with the hypothesis of creep induced movement. However, these markings also corresponded to a partial pull out position of the joint where leakage was possible. Hence, a reasonable expectation would be that the cutting of the groove and the wearing of the flat spot in the AC material would not have been a transitory phenomenon, it is probable that the pipe had resided in this extended, displaced position for some significant time. Hence, I believe that the extra wide black mark, the groove and the flat spot on the pipe spigot at Joint 1 combined to show that in all likelihood this end of the pipe had pulled out of the socket to an extent that leakage was occurring and that this situation had prevailed for some significant time prior to the landslide.

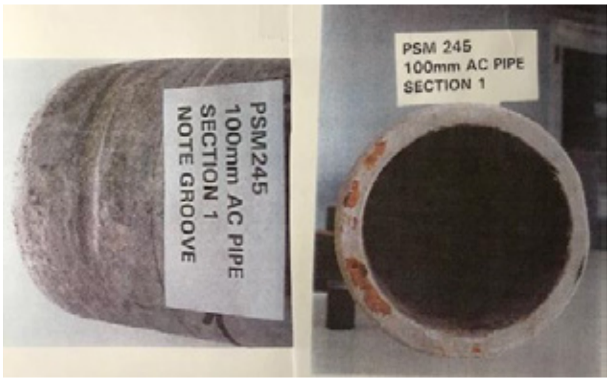

Figure 6: Joint 1 groove and flat spot

In the alternative to the above mechanism, the proponents of the counter mechanism had put forward the proposition that some of the water flowing along the retaining wall trench drain had infiltrated into the underlying extremely weathered granite subsurface and, from there, had penetrated down to the base of the landslide where it had initiated the failure. It had been proposed that the embankment was in such a perilous state of stability that it did not require a large increase in groundwater level to initiate movement, which movement it was then proposed caused the gross leakage at Joint 1.

THE WRITER'S CONTENTION AS TO CAUSE

I did not ever consider the latter proposal provided a likely mechanism for the initiation of the landslide. The early results from the investigation I was overseeing showed that the whole of the slope area beneath the Alpine Way underwent quite large seasonal cyclic variations in ground water level (up to several metres at some locations and at the landslide site in excess of some 1.5m). Measurements made soon after the landslide showed that despite being well into winter, the ground water level was still at a seasonal low as it had been a particularly dry start to winter. Hence, for the landslide to have been triggered by infiltration from the retaining wall trench at that time, it would have been necessary to raise the ground water level at least by some 1.5m in order for it to even enter into the base of the landslide.

An even greater quantity of water can be postulated as being required from infiltration to match the maximum likely to have been flowing during previous winter cycles, which the embankment had successfully negotiated without failure. In an attempt to quantify this effect, it had been necessary for the proponents to assume an infiltration rate, of the water flowing in the retaining wall trench, of up to 20 times the loss measured by PSM. This was an unrealistic assumption which I could not support. On the other hand, leakage from the water main had an effective endless supply of water.

I was also able to observe the site for the many months that it was under police control whilst the retaining wall was still in place (but naturally absent the water main). Hence, I was able to observe the behaviour of the site solely under the influence of the retaining wall. In particular, I noted that at the start of summer the site became very dry, to an extent that all flow through the base stopped - that is, the landslide site completely dried up. During this time I was also taking recordings of the variation of groundwater levels around the site. These showed that the observed drying out of the landslide site was occurring at a time when the groundwater levels were still elevated compared to those that would be recorded in the seasonal low of the early winter months of the following year - and it was during this same seasonal low for groundwater levels in the previous year that the landslide had occurred.

My recordings also established that there was substantial repeatability in the variation of seasonal levels so that a reasonable expectation would be that, given only the influence of the retaining wall, the landslide site would also have been dry at this same time in the seasonal cycle of the previous year; there should have been no groundwater flowing through the base of the landslide at that time of the year. The fact that it had required an elevated level of groundwater to have caused the landslide could only be taken to indicate that the additional water had come from a source additional to that seeping from the retaining wall trench. That is, the actual field performance of site behaviour, absent the water main, was showing that no water would have entered into what would have been the base of the landslide at the time of its occurrence. Therefore, in my opinion, infiltration from the retaining wall trench could not have been the trigger.

THE LEGAL PROCESSES

Ultimately, the two mechanisms of initiation which differentiated the respective sources of water for the trigger were put to the Coroner in the Coronial Inquiry and later before the Honourable Mr Justice Michael J Grove QC in civil action taken out in the Common Law Division of the Supreme Court of NSW. Their respective findings further to their testing of the two theories are given below. Each is taken in turn.

THE CORONER'S REPORT, 29 JUNE 2000

This report is very comprehensive and deals with the many issues related to the landslide, many technical, but also including the history of development and construction at the village, its gradual development, various aspects of the administration and planning relating to its growth, the landslide and the rescue operation. The Coroner considered in great detail the water main and the retaining wall as possible triggers, including evidence from expert witnesses for both hypothesises including intense cross examination of witnesses. In relation to cause, the Coroner made the following findings:-

Summary, paragraph 4.0:

> *I have found in this report that the landslide was triggered when water from a leaking water main saturated the south-west corner of the landslide in the fill embankment of the Alpine Way setting off the first stage of the landslide. The first stage impacted upon the eastern wing of Carinya Lodge. Simultaneously the first stage removed the support of the land to its east causing that, too, to collapse onto the lodges below.*

The Water Main Theory, paragraph 706:

> *Accordingly, I am satisfied that on the balance of probabilities it was a leak from the water main which caused the landslide.*

The Retaining Wall Theory, paragraph 757:

> *In my opinion,* (other expert) *and* (other expert)*'s theories that the retaining wall caused a leak of water which triggered the landslide must fail.*

JUDGEMENT OF THE HONOURABLE MR JUSTICE MICHAEL J GROVE QC, THURSDAY, 2 DECEMBER 2004

The case before Justice Grove involved multiple parties affected by the landslide with particular claims for damages against various government departments involved with the oversight and development of Thredbo and others, plus associated counter claims. In initial hearings there had been a direction for a hearing "... focussed largely upon the cause of the landslide." There were a series of questions posed for Justice Grove to consider and answer in relation to the cause of the landslide, several of which related to the sources of "unnatural" water (as described by Justice Grove) which had caused the landslide. This unnatural water was that which arose either from the retaining wall (referred to below as the Winterhaus Corner retaining wall) or the water main (also referred to as pipeline below) described above.

The answers given by Justice Grove to those questions which relate specifically to the issues discussed above are given below (refer to par 114 of Judgement):

Q1. Was the landslide caused solely, or materially contributed to, by water which came from one or more fractures or leaking joints in the pipeline?

A1. Yes, it was materially contributed to by water from such sources.

Q2. Was the landslide caused solely, or materially contributed to, by water which came from additional flows, if any, resulting from the construction of the Winterhaus Corner retaining wall?

A2. No

Q5, If the landslide was caused, or materially contributed to, by leakage from one or more fractures or leaking joints in the pipeline, was that leakage solely the result of creep in the fill?

A5. Yes. I am not satisfied that the design, construction and maintenance of the water main was unreasonable save in those aspects which did not cater for the long term effects of movement caused by soil creep.

ACKNOWLEDGEMENTS

In addition to the acknowledgement provided for Figure 1, I also wish to acknowledge that the diagram in Figure 3 and the photographs in Figures 4, 5 and 6 were originally sourced from respective "Site Factors" reports prepared for the Coronial Inquest by Pells Sullivan Meynink Pty Ltd. In 2002 these reproductions were used by me in the GHD – LongMac Pty Ltd report which I prepared for the Coronial Inquest.

NOTE

The substitution of the words "other expert" into the text taken from the Coroner's report is an editorial requirement of the Australian Geomechanics Society.

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QUEENSLAND CHAPTER

Limited records exist that detail the initial 10 years of the QLD Group (now Chapter) of the Australian Geomechanics Society (AGS), largely due to the now fading memories of those that were present and the solely technical nature of the original incarnation of the Australian Geomechanics Journal that existed for much of that first decade.

1970 to 1979

Allan McConnell, who can specifically remember that he started working in QLD on 01 July 1969, recalls that he "tagged along" with Peter McAnally (then of Ground Test) to the AGS' events from the time of the society's inception.

Allan recollects that at the time he "... strung along to these meetings but didn't really know what they were", but in hindsight can identify that the topics that were being discussed at some early chapter meetings – for example uncertainties within geotechnical engineering and use of numerical methods for analysis of geomechanics issues – were well ahead of their time.

It was midway through the first decade of the society's existence that QLD hosted it first international conference under the AGS banner – namely the *2nd Australia – New Zealand Conference on Geomechanics.* This Australasian event, a feat that was not to be recreated in QLD until over 20 years later, welcomed 243 registered attendees to Brisbane in late July 1975, at which 61 papers were presented over 4 days. David Williams, who was to go on and become the second longest serving member of the AGS QLD Chapter organising committee, remembers travelling to Brisbane to attend the conference as a 1st year Monash University engineering student, with the intention of meeting prospective PhD supervisors (specifically Dick Parry). He and Allan both recall the highlight of the conference as being a lively debate that was held in the chamber of QLD Parliament house.

The organising committee of the 1975 conference, as recorded in the conference proceedings, reads very closely to the names that repeatedly appear throughout the AGS QLD organising committee of the 1970s and 1980s – specifically Peter Hollingsworth (AM), Bevan Boyce, John Findlay, Peter McAnally and Ralph Rallings. This emphasises the dedication and the longevity of many of the foundation committee members.

In parallel with the development of the program of events provided by the QLD Group of the AGS, the 1970's saw the continued expansion of tertiary geomechanics offerings to regional QLD centres, notably with (David) Hugh Trollope (AO) overseeing the flourishing of what would become a world renowned rock mechanics research group at the James Cook University of Northern Queensland.

Hugh, having moved from Victoria to Townsville acted as the University's Foundation Professor of Civil Engineering (1964-87), before being promoted to Pro Vice-Chancellor (1973-77) and Deputy Vice-Chancellor (1977-87).

1980 to 1989

The 1980's saw considerable growth within QLD's major infrastructure, with the delivery of a series of significant projects throughout the decade – including several coal export terminals (1984), the Brisbane Airport expansion (continuing from 1981), the Townsville and Gold Coast Casinos (both mid-1980s), Wivenhoe Dam and pumped storage hydroelectric power station (by 1985), the original Gateway Bridge crossing of the Brisbane River (1986) and, of course, the 1986 Commonwealth Games and the transformational Expo '88.

By at least 1980, an annual program of approximately 10 events was being routinely delivered by the QLD Group of the AGS. The program typically included 5 to 7 technical papers delivered by local and visiting geomechanics professionals on a Thursday evening at the Hawken Auditorium – at what was, until late 2019, the home of the QLD Division of The Institution of Engineers, Australia. The meetings of the organising committee were scheduled for the alternate Thursday fortnights to complement the technical evenings. As all personnel that were interviewed for this retrospective reminisced, this schedule was adhered to in a near religious manner throughout the '80s and '90s with the exception of a short period in early 1985, in which the "industrial turmoil" that caused power blackouts in Brisbane forced the committee meetings to be temporarily re-located to the Victory Hotel – which was selected as an acceptable venue based on it being the only location to be "able to supply their own candles and refrigeration".

The balance of annual QLD events appeared to evolve throughout the 1980's, with annual field trips to a local major engineering project (e.g. Wivenhoe in 1981 and Brisbane Airport in 1982) and student nights (1980 – 84) yielding to annual dinners and debate events (onwards from 1987). 1988 also saw the return of the AGS to QLD Parliament house, with a special Australian bi-centennial debate event held between geotechnical and civil engineers alongside barristers and property developers.

A series of half and full-day symposiums was added to the AGS calendar of events from 1981 and continued throughout the decade, with two such events typically occurring each year. These were frequently noted as the highlight and most popular of the AGS annual program, with attendances of up to 125 personnel being recorded. Such large and repeatable attendances at these semi-annual symposium events indicate a very engaged QLD based geomechanics community, and are comparable (or exceed) the attendance numbers being attracted to similar symposia held today, 40 years later.

The feat becomes even more commendable when considered in context with the total national membership of the AGS being only 384 (1981) to 730 (1990) – obviously non-AGS members made up a significant portion of the attendance numbers at these events.

The record of such an active industry and annual calendar of events does suggest the humility included in the recalled memories of those present at the time – as it has been suggested that Brisbane only had a "very small" community of geomechanics professionals during this period and that the early AGS events were really only regularly attended by a small handful of people.

Throughout 1984 to 1986, the QLD Group undertook several industry advocacy tasks, with the development of a position paper on house foundations – Ground Movements and House Footings. This was publicly issued as a simple handout to alert interested parties (home-owners and builders in particular) about common ground movement issues associated with foundations installed upon clay sites and suggestions for house and site maintenance. As a separate exercise the QLD group also conducted and reported upon a survey to clarify the industry demand, training requirements and expectations associated specifically with Engineering Geologists.

Inter-societal and other relationships were also developed by the AGS Committee, with joint events held with the Engineering Geology Specialist Group, AusIMM, the Geological Society of Australia and the Structural Group of the Institute of Engineers. The QLD AGS group represented the society upon the Statutory Building Regulation Committee, the Domestic Footings code development committee with the Standards Association, as geotechnical experts advising Local Government Department committees and the Master Builders Association development of a domestic construction manual. The long-standing relationship between AGS QLD and John Wagstaff was also established by early 1983, with co-hosted technical events and seminars on piling related topics occurring on a semi-regular basis from this time onwards.

Within QLD itself, and on the periphery of the AGS, other tertiary institutions were being assisted by the AGS QLD Group and developed the capabilities of the geomechanics industry – specifically, the part-time residential Master of Engineering Science degree (rock engineering) repeatedly offered by James Cook University over each (approx.) two-year period and, from 1985 onwards, workshops offered by The University of Queensland (with David Williams having relocated permanently to Brisbane in 1983, and joined by Andy Fourie in February 1985).

The names of international speakers that presented at QLD AGS events through the '80s also reflects the quality of the events that were being organised at the time. The QLD Group were graced with the presence of industry luminaries like Bengt Broms (President of the International Society of Soil Mechanics and Foundation Engineering (ISSMFE), 1985-89), Walter Wittke (President of the International Society for Rock Mechanics (ISRM), 1979-83), Dick Parry (Secretary General of ISSMFE, 1981-99), Michael Duncan (1991 Terzaghi Lecturer) and Milton Harr (ASCE Geo-Institute "Hero"). The regular presence of such eminent presenters can in part be explained by the presence of outside events, such as the ISRM Conference (Melbourne, 1983), and contemporary projects (e.g. Bougainville Copper development being resourced from Brisbane offices). A number of these international visitors also visited and made additional presentations at locations outside Brisbane - including visits to Mt. Isa (in conjunction with Mt. Isa Mines) and Townsville (in conjunction with James Cook University).

During this period The Institution of Engineers, Australia would apparently not reimburse the AGS QLD Group or directly pay for anything. Furthermore, as any money declared to the parent body during this period appeared to simply 'disappear' into their coffers, past AGS Group chairs Allan McConnell (Chair 1982) and David Williams (Chair 1984) both now admit to using their personal bank accounts to secret away the Group's receivings and having full discretionary access to a QLD Chapter chequebook.

Peter Hollingsworth (AM) – truly a leading light in the development of geomechanics as a recognised profession in Australia – lead from the front during the early 1980's within his position as the AGS National Chair (noting that this was the only time within the 50 year history of the AGS that a QLD based geomechanics practitioner has lead the National Committee). During his chairmanship (1980/81) he oversaw the commencement of the publication of the *Australian Geomechanics News* – arising from the failed annual publication of *Australian Geomechanics* Journal (1971-79) – such that an informal conduit between the National Committee and AGS members could be maintained and a closer relationship between the state-based groups fostered. Peter would also personally host international guests at his family property during their visits to Brisbane, with each contemporary report noting that all visitors were encouraged to sample the local beer – and Peter himself earning the nickname of "iron tooth" Hollingsworth due to his ability to open such products without the need for a bottle opener. At the same time (1980 to at least 1983) Peter was also busy representing the AGS on various task forces – including the Task force on National Disasters, Working Party on Offshore Codes of Practice and the Working Party to consider the implication of a 200 mile exclusion economic zone around Australia.

Allan McConnell and David Williams both recall that Peter Hollingsworth would frequently co-opt the monthly AGS meetings – where he would turn up to QLD Group events with a box full of slides and wait until the call for "any further questions" rang out.

Apparently, Peter would reply with "I've got one" and proceed to make a short, albeit very entertaining, presentation about a completely different topic – including his recent experiences with scuba diving with sharks, bamboo farming in the Brisbane Valley and crossing rivers whilst dodging crocodiles during the development of a new mine in PNG.

Peter was not alone in offering such steadfast and ongoing support of the QLD AGS. A significant number of other people served on the QLD Group's organising committee for most (if not all) of the 1980s; including Bevan Boyce, Graeme Boyd, Geoff Eades, Mike Marley, Peter McAnally, Allan McConnell, Russell McConnell, David Nolan, Keith Wallace and David Williams.

Special mention must also be given to Peter McAnally, who was a driving force both within the QLD Chapter and nationally within the AGS until his sudden death in September 1983. As remembered in the subsequent editions of the *Australian Geomechanics News* – a publication that he had himself edited from early 1982 to the time of his death – he was intimately involved with the organisation of all activities of the Queensland Group and represented the body upon statutory building regulation committees. Allan McConnell also remembers Peter fondly, and recognises him as the "one of the smartest people he has ever encountered" and whose fingerprints remain, to this day, easily identifiable across Brisbane's heavily utilised infrastructure. The Queensland Institute of Technology (QIT, now QUT) recognised Peter's contribution with a named annual lecture – the Peter McAnally Memorial Lecture – which was incorporated into the AGS' calendar of events for the first 2 iterations. The inaugural address was made by Professor Milton Harr (Purdue University) in November 1983, followed by George Goble (University of Colorado) in June 1985.

It was with interest that the source material reviewed for this historical perspective continually noted how the QLD group of the AGS were, throughout the 1980s, grappling with the same issues that continue to be presently debated, including:

- How to increase membership numbers and is the AGS subscription providing value for money [I note the membership fee was set at $22 in 1982 for those who also held I.E.Aust memberships].
- Possibility for the AGS to incorporate industry recognition of technical grades and other geomechanics practitioners who were otherwise ineligible for I.E.Aust admission.
- How to potentially assimilate data collected by various parties into a sole source accessible by all in the industry (e.g. published geological maps or a publicly available database). It is noted that two special projects attempted by the QLD Group to collate geotechnical data collected by the entire community – the development of a soils map of Brisbane (1984 - 86) and a geological map of the inner city area of Brisbane (1988, as a bicentennial project) – never came to fruition due to the inability to obtain all the required information.
- Struggling with the way to effectively deliver events to the entire QLD membership due to the remoteness of many work locations and distance between major centres where geomechanics practitioners are clustered. The noted looming risk was that the Chapter would become Brisbane centric. In 1983, records note that John Simmons (then of James Cook University, Townsville) was the first QLD Group committee member in many years to be not living in Brisbane.

1990 to 1999

The 1990s saw a continuation of the development of QLD's infrastructure. Within the South East corner this development included the creation of multiple canal estates and the re-development of the Brisbane Casino; a project which involved significant excavation immediately adjacent to, and underpinning of, sensitive heritage buildings. The decade also saw the ongoing expansion of the state's mining sector and the incessant upgrade of the state's transport infrastructure – including the continual widening of the Brisbane to Gold Coast road link and removal of the last remaining timber bridges from the Bruce Highway.

Within the ranks of eminent QLD practitioners, Peter Hollingsworth (AM) started off the decade by being elected into the executive (vice president) of the Institution of Engineers, Australia. At the same time, Ted Brown (AC) was promoted to Deputy Vice-Chancellor (1990) of The University of Queensland (UQ), after having returned to QLD in 1987 to become the University's 1st first full-time Dean of Engineering. Ted Brown, an alumnus of the university at which he was now employed, also had the illustrious distinction of having been the first Australian to hold the presidency of one of the AGS-affiliated international bodies, having served as the ISRM President between 1983-87.

The annual program of the AGS QLD Group continued on through the 1990s as it had ended the 1980s – with a reliable annual program of near-monthly technical events. As per those involved in the society in the 1980s, the regimented schedule of committee and society meetings occurring on alternate fortnights between February and November was a commonly recalled theme of the period. Stability within the organising committee again remained a feature throughout the 1990s, as exemplified by the extensive ongoing service provided by Bevan Boyce and Robert Morphet (9 years each), alongside David Williams, Burt Look and Michael Neighbour (7 years each).

The early 1990's saw the QLD Group focus on the legal aspects associated with practising geomechanics, with the formation of a "Litigation Sub Committee" in 1990 and presentations upon similar themes recurring within the annual program between 1990 and 1993. Multiple piling symposia were also held during this time, with two dedicated symposiums held in the period between 1991 and 1995 – the latter due to the release of the AS2159 Piling Code – and an additional QLD Group subcommittee formed to report on the inspection of bored pile shafts in 1992, at the direction of the National Committee.

Other regular events in the annual program included joint events with the Geological Society of Australia (6 over the decade), as well as joint meetings with the Queensland Division of the Institute of Engineers Structural Group (5 events) and Footings Panel (3 events). An end of year social dinner was also instituted during this time, initially conceived as a private event for the committee handover, then a social event open to all chapter members and finally, by 1997, an event that also incorporated the Chapter's AGM. The award for the most frequently utilised technical presenters for the decade was shared between David Starr, David Williams, John Simmons, Robert Day and Robert Haynes (4 each).

Even though the timing and location of the AGS events did not dramatically change throughout the decade, a change in parking conditions near the Hawken Auditorium at a specific point in the mid-nineties memorably caught a number of AGS members out at the following meeting. Burt Look (Chair 1999) remembers clearly that he was one member who returned to his car after attending a technical evening to find that he had been fined for parking within a newly defined clearway, whereas up to that point it had always been legal (and the most convenient) place to park prior to AGS events.

1995 and 1996 also saw the return of editing duties of Australian Geomechanics to the QLD Group, a task last undertaken by the Chapter in 1983. As per that previous iteration, this task was undertaken by the members of the committee based at QUT – Keith Wallace, Bevan Boyce – and Pat Wilson (Coffey Partners).

Technology also played a part in the QLD group's activities, with videotaping of technical events commencing such that the videos could be loaned to non-Brisbane based members. This was anticipated to assist in providing value to the more remote of the AGS QLD membership and select events were being recorded by 1998. However, from all reports, the requests for borrowing the recordings were largely disappointing from the outset.

Burt Look remembers his time on the committee during the 1990s was full of faxing event reminders the week (and days) before AGS events to all major geomechanics practitioners around Brisbane. However, due to the lack on an RSVP requirement (or a readily available email system) he was always nervous that there would be either no one in attendance or the Hawken Auditorium would be overcrowded.

Similarly, as each event (day) organiser assumed personal responsibility for the catering and beer to be served at the event – the latter introduced by the organising committee as an 'enticement' for people to attend the technical evenings – the lack of an RSVP system and the fact that attendance could "range from 20 to in excess of 70, depending on interest in the topic" meant that correctly estimating the required quantities of refreshments required for each event was an art in itself.

The major additional project attempted by the QLD Chapter through the 1990s was to complete a study on the Engineering Geology of Brisbane, with the committee having been inspired by similar projects being completed in Sydney, Melbourne and Newcastle. An interesting record of the project's advancement can be found by a progressive review of *Australian Geomechanics* – with the project originally mooted in 1992 with a call for interested parties to become involved to develop and deliver a symposium on the topic in 1994. By 1993 the envisaged delivery had changed to become a significant publication, but progress was repeatedly stalled once the enormity of the undertaking was realised and the limited availability by those involved. Throughout 1996 and 1997 it was recorded the project (now aimed at delivery via a symposium and accompanying book, to be held in 1998) was still progressing, albeit at a snail's pace and without any direct funding – Burt Look recalls attending meetings being called by the dedicated subcommittee, and then only 2 of the numerous persons involved actually turning up. In 1998, the QLD chapter confirmed that the project would be delivered in symposium format as the highlight of the technical program for QLD's 1999 calendar, and, on 29 October 1999 – some 7 years after the first note of the project's inception – 12 presenters indeed delivered *The Engineering Geology of South East Queensland* to a fully booked symposium audience.

2000 to 2009

The geomechanics community within QLD grew enormously throughout the first decade of the new millennium, driven largely by the rapid (and unrelenting) development and expansion of QLD's mining industries and associated infrastructure. With the related population explosion within the urban areas of the state, the decade also saw the commencement and commissioning of significant transportation and tunnelling projects throughout South East Queensland – including the opening of the South East Transit Project (SEBT), the Inner City Bypass, duplication of the Gateway Motorway, Port of Brisbane Motorway and the North-South Bypass Tunnel (NSBT, now Clem7).

The AGS QLD Chapter membership during this period similarly experienced rapid growth, increasing by 50% from 160 to 239.

The early 2000's was a transformational time for the AGS QLD Chapter, with the injection of younger engineers and more diversity into the group's organising committee. This drove some significant change that resulted in both the committee meetings and member events being less restrictive and formal. As Symon Jackson recalls, when he joined the AGS committee in 2000 as a 27-year-old, he was at least 10 years younger than anyone else on the committee and he found the meetings were an almost "church-like" experience – with, once the formal recognition of having achieved a quorum and adopting the previous minutes, the prescribed agenda items being addressed by the committee in "a machine like fashion".

The traditional venue for chapter events – Hawken Auditorium at Engineers House – was recognised to have become dull, dated and uninspiring. Thus, a conscious decision was thus made to untether the Chapter's technical presentations from the confines of the QLD home of Engineers Australia (themselves having updated their trading name to EA in 2003), and for the society to host their events at more 'accommodating' venues around the city. This was progressively achieved through the late 2000s, with only the occasional technical meeting being held at EA premises by 2010. Alternative venues now included function rooms at New Farm, Griffith University, the Irish Club and Treasury Casino Hotel within Brisbane City. This change of venue – and potentially the improved availability of an accompanying drink at meetings – was welcomed by chapter members and resulted in a notable increase in attendance at the monthly meetings.

The new millennium saw the QLD Chapter commence regular hosting of Rankine lecture events, with Professor John Atkinson presenting the first Brisbane presentation in 2000. The new century also saw a renewed focus on the younger generation of geotechnical engineers, under various guises. A student prize was initiated in 2000 to reward the best undergraduate geotechnical thesis with a small cash award. This award initially garnered widespread interest – with six QLD based universities represented in the initial year's submissions – but as the award submission required a re-working of a student's final year thesis after they had effectively finished their university course, it quickly became hard to attract nominees. However, the commitment to developing geomechanics professionals was sustained, with the incorporation of a "Young Geotechnical Representative" position to the organising committee and the commencement of physical visits by the AGS to local universities undertaken from 2002. The mid-2000's also saw a dedicated Young Engineers event being added to the annual calendar – typically in the form of a networking event that involved an evening boat cruise along the Brisbane River. This became an extremely successful event that ran for many years, and special mention needs to be given to the advocacy, financial sponsorship and obvious passion provided by Allan McConnell – both specifically to the QLD Chapter boat cruise events and to the wider, unwavering support he has offered to younger members of the AGS and the biennial ANZ Young Geotechnical Professional Conferences (YGPCs) events.

Another major milestone observed by the QLD AGS Chapter during the 2000's was the retirement of Bevan Boyce in 2005. Bevan was the final Chapter Committee member whom had been involved in the organisation of QLD events in a near continuous capacity since the AGS's conception in 1970, and whom had served as the Chapter's Treasurer for most of those 35 years. As all those interviewed for this project reminisced, Bevan became infamous for providing his Treasurer's report at committee meetings via distributing handwritten summaries meticulously copied onto multiple small strips of paper that had been cut from a larger A4 sheet. Bevan remains the longest serving AGS QLD Chapter committee member to date.

At approximately the same time as Bevan's departure, Symon Jackson recalls there was uproar within the Chapter due to significant changes to the Treasurer's responsibilities. The newly installed National AGS Secretary, Peter Robinson, demanded that the Chapter's yellow Commonwealth Bank cheque book – which by all reports was tightly held and monitored by Bevan as it was the only means of making Chapter payments – be returned in conjunction with all Chapter bank accounts being consolidated. Although at the time there was a sense of dread and anxiety in terms of how such a move would see the National Committee curtailing the autonomy of each Chapter, it can (with the benefit of hindsight) be identified as one of the best decisions that the AGS made!

The mid-2000's also welcomed the return of major technical conferences to QLD after an absence of nearly 30 years. Initially, 2004 saw the Gold Coast host the *6th ANZ Young Geotechnical Professionals Conference (6YGPC)*, whilst the flagship quadrennial ANZ conference returned to Brisbane in the October of 2007 with *Common Ground: 10th Australia – New Zealand Conference on Geomechanics*. Both events remain among the most successful of their conference series, with personnel involved with the organisation of both the YGPC (Symon Jackson) and the ANZ Conference (Burt Look) individually recalling that deliberate and intense efforts were made to achieve the highest possible sponsorship and delegate numbers, in order to elevate the profile of the events whilst at the same time remaining financially independent of the AGS itself (which, nationally, was not in a financial position to offer significant subsidisation to such events).

Due to the successful nature of these QLD based conferences, in which both events returned a profit back to the AGS National Committee, they became the benchmark in terms of event quality and learnings made during their organisation continue to be implemented within more recent iterations.

Along with case studies of Brisbane and QLD based major projects, other notable trends in the Chapter's technical presentations during the decade included a focus on ground stability issues – both relating to slope stability (with multiple presentations made on the ongoing development of the AGS' Landslide Risk Management resources, the findings of the Thredbo Landslide inquiry and aspects of slope stability relating to mining operations) and ground subsidence / dealing with historical mine workings within an urban context. The infrastructure boom experienced by QLD during this period also helped to cement the close working relationship that still exists between the QLD based groups of the AGS and the Australian Tunnelling Society (ATS), with whom joint events have been regularly held since approximately 2006.

2010 to 2019

The ongoing infrastructure and mining development of QLD saw a sustained increase in both the local geomechanics community and the membership of the QLD Chapter of the AGS. With 468 members by the end of 2019, the QLD Chapter size had increased by 95% over the decade and had developed to become the 2nd largest AGS Chapter within Australia (behind the Sydney Chapter).

Many of the annual events instigated during the 2000's continued to be incorporated regularly into the QLD Chapter calender for at least a portion of the most recent decade – including the annual boat cruise (continued until 2013), a joint event with the Women in Engineering Group (2009 to 2014), and student outreach to QLD Universities and student oriented presentation events (continued to date). A full day, annual technical symposium of the QLD Chapter was also added to the calendar in a regular capacity in 2011 (with such symposia having been typically held ad-hoc or of a lesser (half-day) duration prior to this), with the event's theme changed each year.

2012 was a particularly tumultuous year for the QLD Chapter, with the serving Chair (Erwin Oh) having to resign due to health and workload reasons. At the same time, a number of other committee members also found that their current work commitments prevented effective contribution to Chapter events – and thus the unprecedented event of not being able to achieve a quorum of the organising committee became a real possibility for the Chapter. Symon Jackson (Chair 2010/11) remembers early 2012 as an uncertain time for the Chapter, with a sudden slowing of activities from the normal active, near-monthly events to only a single locally organised technical evening held in the first 8 months of 2012. Realising that a reinvigoration of the Chapter was required, Theo Gerritsen and Symon Jackson took the reins as co-Chairs and commenced revitalising the organising group (and thus the Chapter as a whole). This modernisation included seeking annual sponsors of the Chapter, with the view that a financially secure chapter could deliver greater services to its members – to which particular thanks should be given to both John Wagstaff (Wagstaff Piling) and Allan McConnell (IGS) for their long-standing support in such roles.

The Chapter's revitalisation was dramatic under Theo Gerritsen's energetic stewardship (Chair 2012/13), with the Chapter successfully delivering an unprecedented 19 technical events to members throughout 2013. This reinvirgoration also included new relationships with previously unaffiliated societies – including holding joint events with the Bowen Basin & Hunter Valley Open Cut Geotechnical Society (BOHOGS) – and consciously trying to widen the topics presented at technical events in order to appeal to the largest possible audience of geomechanics practitioners.

In notable contrast to the stability of the core of the Chapter committee observed over previous decades, rapid change to the committee leadership was not an isolated event throughout the 2010's. It appears that during the middle of the decade, by agreeing to serve on the AGS QLD Chapter executive one would significantly increase their risk to being required for significant non-Queensland based roles. Multiple people had to relinquish their executive roles due to an interstate or international relocation; including Theo Gerritsen himself (whilst serving as Immediate Past Chair, 2015), Sevda Dehkhoda (Chair elect, 2014), Nicole Tucker (Chair elect, 2016) and Vladimir Lopez (Immediate Past Chair, 2017). Resisting this change were the stalwalts of the AGS QLD Chapter – Allan McConnell and Professor David Williams – whom both provided continued and valuble guidance to each successive leadership group over the full decade.

Despite this, largely unavoidable, churn within the organising committee, the AGS QLD Chapter was still able to deliver significant events and projects, external to the provision of the traditional annual calendar of technical evenings and training programs. Undoubtedly the largest and most sustained undertaking has been achieved by Timothy Thompson (Chair 2016/17), whom commenced working tirelessly in 2015 to try and collate borehole logs and geotechnical data relating to Queensland sites into a publicy accessible database platform. By launching the Queensland Geotechnical Database (www.qgd.org.au) in 2017 (with Jared Priddle – QLD AGS committee member, 2018/19), this saw the modern delivery of a project that was envisaged by the QLD Group of the AGS in the 1970's and that had been repeatedly abandoned through the 1980's and 1990's due to its complexity.

This database has continues to be updated to date, has now grown to include over 1,600 geotechnical logs that date back to 1966 with contributions from multiple engineering consultancies and public entities.

International conferences continued to be organised by QLD based AGS personnel, with Noosa playing host the 10th iteration of the co-branded AGS-NZGS' *ANZ Young Geotechnical Professionals Conference (10YGPC)* in September 2014, organised by David Lacey (Chair 2018/19). Allan McConnell was instrumental in campaigning for the award and delivery of the significantly larger *5th International Conference on Geotechnical and Geophysical Site Characterisation (ISC'5)* to the Gold Coast, which, with AGS support, was successfully staged in September 2016.

During the last 10 years, QLD based AGS members have also been particularly successful in being the recipient of the AGS' National Awards – with John Simmons (2014) and Burt Look (2018) becoming the only QLD based members to have received the biennially bestowed *AGS Practitioner Award*. Similarly, a QUT research team – with lead author Biyanvilage Dareeju – were the recipients of the 2018 *Australian Geomechanics Award*, and thus became the only QLD based authors to have achieved this feat. The younger generation also were recognised by the AGS, with David Lacey (2012), Nigel Ruxton (2016) and Nicola Manche (2018) all being awarded the *Don Douglas Youth Fellowship* during the decade, and followed in the footsteps of Scott Fidler (2000) as being QLD based AGS members to have received this honour.

SUMMARY OF QLD AGS KEY EVENTS, AWARDS AND PERSONNEL (1970 – 2019)

QLD organised AGS Supported Conferences:

- 2nd Australia – New Zealand Conference on Geomechanics – Brisbane, July 1975
  - QLD Organising Committee – W. Vance (Chair), Bevan Boyce, John Findlay, Peter Hollingsworth, Peter McAnally and A. Wickham
- 6th Australian – New Zealand Young Geotechnical Professionals Conference (6YGPC) – Gold Coast, July 2004
  - QLD Organising Committee Members – Symon Jackson, Karen Allen and Patrick Kidd
- 10th Australia – New Zealand Conference on Geomechanics – Brisbane, October 2007
  - QLD Organising Committee – Burt Look (Chair), Jay Ameratunga, Beng Cheah, David Starr, Brett Taylor and Chris Thorley
- 10th Australian – New Zealand Young Geotechnical Professionals Conference (10YGPC) – Noosa, September 2014
  - QLD Organising Committee – David Lacey (Chair & Secretary)
- 5th International Conference on Geotechnical and Geophysical Site Characterisation (ISC'5) – Gold Coast, September 2016
  - QLD Based AGS members – Allan McConnell and Richard Kelly

QLD based members acting as AGS National Committee Chair / International Member Society President

- E.T. (Ted) Brown – President of ISRM, 1983 – 1987 (the first Australian to have served as a president of any of the AGS affiliated international societies – ISRM, IAEG or ISSMGE)
- Peter Hollingsworth – AGS National Chair, 1979 – 1981 (only QLD based member to have served as the chair of the AGS)

QLD based recipients of National AGS and International Member Society Awards:

- John Jaeger Memorial Award (JJMA) – *To recognise contributions of the highest order over a lifetime commitment to the geotechnical profession in Australia:*
  - Brian Richards – 1992 (4th) JJMA
  - E.T. (Ted) Brown – 2004 (7th) JJMA
- AGS Practitioner Award – *Awarded for the contribution of the highest order to the geotechnical profession in Australia and the Australian Geomechanics Society over an extended period:*
  - John Simmons – 2014 (6th) AGS Practitioner Award
  - Burt Look – 2018 (8th) AGS Practitioner Award
- Don Douglas Youth Fellowship (DDYF) – *Awarded to author of the most outstanding paper at an ANZ Young Geotechnical Professional Conference (YGPC):*
  - Scott Fidler – 2000 (1st) DDYF
  - David Lacey – 2012 (6th) DDYF
  - Nigel Ruxton – 2016 (8th) DDYF
  - Nicola Manche – 2018 (9th) DDYF
- D.H. Trollope Medal – *Awarded for an outstanding paper on either theoretical or applied geomechanics to an author under 35 years of age:*
  - Bastian Otto – 1992 (3rd) D.H. Trollope Medal
- Australian Geomechanics Award – *Recognising the author/s of the best paper published in Australian Geomechanics Journal in each calendar year:*
  - Biyanvilage Dareeju – 2018 (17th) Australian Geomechanics Award (awarded to multiple authors from a Queensland University of Technology (QUT) research team)

- International Society for Rock Mechanics (ISRM) Awards:
  - Thomas Kleine – 1991 Rocha Medal – *for an outstanding doctoral thesis*
  - E.T. (Ted) Brown:
    - 2007 (5th) Muller Award – *in recognition of distinguished contributions to the profession of rock mechanics and rock engineering*
    - 2011 (inaugural) ISRM Fellow – *for outstanding accomplishment in the field of rock mechanics and/or rock engineering*

QLD AGS Chapter – Longest Serving Committee Members

- Bevan Boyce – 35 Years (1970*-1992 and 1994-2005)
- David Williams – 33 Years (1984-1990 and 1994-2019)
- Allan McConnell – 24 Years (1981-1989 and 2005-2019)
- Beng Cheah – 17 Years (1995-2011)
- Symon Jackson – 16 Years (2000-2015)
- Peter Hollingsworth – 15 Years (1970-1984)
- Peter McAnally – 14 Years (1970*-1983)
- Burt Look – 13 Years (1993-2001 and 2004-2007)
- Andrew Middleton – 13 Years (1990-1992 and 1997-2005)
- Andrew Massey – 12 Years (1997-1998 and 2000-2009)

*Note that due to lack of detailed records prior to 1980, some interpretation regarding the QLD Chapter Committee membership within the initial 10 years (1970 – 1979) has been required – based on National Committee and ANZ Conference organisation records, supplemented by recollections provided by contemporary sources.

The authors of this brief QLD Chapter History would like to specifically acknowledge the contributions from Professor David Williams, Dr. Burt Look, Allan McConnell and Peter Hollingsworth (AM), whom were all interviewed as part of this project.

Inevitably, due to the limited available source material, the detail included in this history will have overlooked important events, awards and key personnel active in the QLD geomechanics community. The authors sincerely apologise for any omissions and would welcome feedback such that the heritage of the AGS QLD Chapter can be preserved.

Furthermore, it is recognised that only minor information regarding the QLD Group's activities were available for the 1970-79 decade, due to the absence of accessible records. However, based on the personnel who made up the QLD based organising committee from the inception of the AGS in 1970, this lack of detail is not considered to be representative of any lesser group activity during this period.

Meeting of 3 generations of AGS QLD Chapter Chairs – (L-R) Symon Jackson (2010 Chair), Peter Hollingsworth (1970 Chair & 1979-81 National AGS Chair) and David Lacey (2018/9 Chair)

This article was prepared by David Lacey and Symon Jackson

<table>
<tr><th colspan="5">QUEENSLAND CHAPTER COMMITTEES</th></tr>
<tr><th>Year</th><th>Chair</th><th>Deputy Chair</th><th>Secretary</th><th>National Representative</th></tr>
<tr><td>1970-72</td><td colspan="3" rowspan="4">No Specific Records Available</td><td>Mr K Matthews / Mr Peter Hollingsworth</td></tr>
<tr><td>1973-75</td><td>Mr Peter Hollingsworth</td></tr>
<tr><td>1976-78</td><td>Mr A Wickham</td></tr>
<tr><td>1979</td><td>Mr Bevan Boyce</td></tr>
<tr><td>1980</td><td>Mr Malcolm Ballinger</td><td></td><td>Mr John Findlay</td><td>Mr Bevan Boyce</td></tr>
<tr><td>1981</td><td>Mr Graham Boyd</td><td>Mr Allan McConnell</td><td>Mr Russell McConnell</td><td>Mr Neil Robertson</td></tr>
</table>

QUEENSLAND CHAPTER

Year	Chair	Deputy Chair	Secretary	National Representative
1982	Mr Allan McConnell	Dr John Carter	Mr Russell McConnell	Mr Neil Robertson
1983	Mr Mike Marley	Mr David Nolan	Mr Russell McConnell	Mr Neil Robertson
1984	Mr David Nolan	Dr David Williams	Mr Russell McConnell	Dr David Williams
1985	Dr David Williams	Mr Bruce Butler	Mr Russell McConnell	Dr David Williams
1986	Mr Bruce Butler	Mr Russell McConnell	Dr Norbert Baczynski	Dr David Williams
1987	Mr Russell McConnell		Dr Norbert Baczynski	Mr Russell McConnell
1988	Mr Doug Maconochie / Geoff Eades		Mr David Nolan	Mr Russell McConnell
1989	Mr Geoff Eades	Mr David Starr	Mr David Nolan	Mr Russell McConnell
1990	Mr David Starr	Mr Paul Wallis	Mr David Nolan	Mr Paul Wallis
1991	Mr Paul Wallis		Dr Scott Fidler	Mr Paul Wallis
1992	Mr Robert Morphet	Dr Alan Moon	Mr Bruce White	Mr Paul Wallis
1993	Mr Robert Morphet	Mr Bruce White	Mr Bruce White	Mr Paul Wallis
1994	Mr Bruce White	Mr Paul Glover	Mr Paul Glover	Mr Robert Morphet
1995	Paul Glover / Dr John Simmons	Dr John Simmons	Mr Michael Neighbour	Mr Robert Morphet
1996	Dr John Simmons	Dr Robert Day	Mr Michael Neighbour	Mr Robert Morphet
1997	Dr Robert Day	Dr Burt Look	Mr Murray Geale	Dr John Simmons
1998	Mr David Stewart	Dr Burt Look	Mr Murray Geale	Dr John Simmons
1999	Dr Burt Look	Dr Scott Fidler	Mr Andrew Middleton	Mr Robert Haynes
2000	Dr Burt Look		Mr Symon Jackson	Mr Robert Haynes
2001-02	Mr Robert Haynes	Mr Andrew Middleton	Mr Symon Jackson	Mr Chris Thorley
2003	Mr Andrew Middleton	Mr Chris Thorley	Mr Symon Jackson	Mr Chris Thorley
2004	Mr Andrew Middleton	Mr Chris Thorley	Mr Symon Jackson	Mr Beng Cheah
2005	Mr Chris Thorley	Mr Beng Cheah	Mr Symon Jackson	Mr Beng Cheah
2006	Dr Jay Ameratunga	Mr Beng Cheah	Mr Symon Jackson	Mr Beng Cheah
2007	Dr Jay Ameratunga	Mr Beng Cheah	Mr Symon Jackson	Prof David Williams
2008	Mr Beng Cheah	Mr Symon Jackson	Dr Erwin Oh	Prof David Williams
2009	Mr Beng Cheah	Mr Symon Jackson	Dr Erwin Oh	Ms Diane Mather
2010	Mr Symon Jackson	Mr Mike Straughton	Dr Erwin Oh	Ms Diane Mather
2011	Mr Symon Jackson	Mr Mike Straughton	Dr Hongyu Li	Ms Diane Mather
2012	Mr Erwin Oh / Mr Theo Gerritsen / Mr Symon Jackson	Mr Theo Gerritsen	Dr Hongyu Li	Mr Symon Jackson
2013	Mr Theo Gerritsen	Dr Hongyu Li	Dr Sevda Dehkhoda	Mr Theo Gerritsen
2014	Mr Vladimir Lopez Suarez		Mr Nathan Gooch / Ms Nicole Tucker	Mr Vladimir Lopez Suarez
2015	Mr Vladimir Lopez Suarez	Mr Timothy Thompson	Ms Nicole Tucker	Mr Vladimir Lopez Suarez
2016	Mr Timothy Thompson	Dr David Lacey	Dr David Lacey	Mr Timothy Thompson
2017	Mr Timothy Thompson	Dr Sevda Dehkhoda	Ms Natalie Campbell	Mr Timothy Thompson
2018	Dr David Lacey	Ms Natalie Campbell	Mr Matthew Stewart	Dr David Lacey
2019	Dr David Lacey	Mr Chris Bridges	Mr Matthew Stewart	Dr David Lacey

2000 TO 2009

HIGHWAYS AND BYWAYS

The Cumbalum area of the Ballina Bypass Alliance project, showing the low-lying landform. One of the innovations of the project was treating the 25m deep soft soil using, for the first time in Australia, the vacuum consolidation technique at the southern approach of Emigrant Creek North. A total of 14m of fill was placed and 6.5m of settlement took place.

The decade of the new Millennium saw an explosion of highway projects, evident from the $77.3 billion federal and state government funding in this period. Over half of this amount was allocated to NSW (34%) and QLD (27%) roads. At the same time the Alliance project delivery came into play, moving from the traditional D&C approach towards a relational approach that has been gaining momentum for highly complex and/or highly time-constrained infrastructure projects. Geo-professionals are seen as crucial partners in Alliance projects due to the inherent risks associated with ground works and opportunities to value add. The first alliance road project during this decade commenced with the Port of Brisbane Motorway in QLD in 2000, followed quickly by NSW for the Lawrence Hargrave Drive/Seacliff Bridge in 2003, then the first alliance on the Pacific Highway Upgrade program for the Ballina Bypass section in 2008 to deal with the challenging soft soil issues. In this Chapter, you will find many geotechnical lessons learnt from some of the road projects constructed during this decade.

PROFESSOR JOHN CARTER CHAIR 2000-01

AGS comes of age in the new Millenium.

I can't remember exactly when I first joined the Australian Geomechanics Society, but I am clear that it had to have been in the 1970s when I was a PhD student at the University of Sydney under the considerable influence of Ted Davis, Harry Poulos, John Booker and Peter Brown, who were academic staff members of the University of Sydney and without question amongst the "gurus" of geotechnics at that time in Sydney, as well as nationally. My joining the Society had to be at the urging of one or more of those mentors.

I then had a period away from Sydney, in the UK (Kings College London and Cambridge University) and then Brisbane (University of Queensland), only to return home in late 1982. It was almost straight after my return to Sydney that I resumed my active membership of the Sydney chapter of AGS.

I learned much as younger man by attending Sydney Chapter meetings throughout the 1980s, and the lessons were not all about geotechnics. Learning about the local personalities in our engineering discipline was very enjoyable, and I can tell you those personalities were not in short supply at that time! Most were eager to debate technical points and to make their points forcefully and often effectively. I probably learned just as much from listening to these exchanges as I did from the more formal presentations.

I first joined the Sydney Chapter Committee in 1990 and eventually, as chair of that Chapter, I became a member of the National Committee in 1996. I was national chair in the years 2000 and 2001 and remained on the national committee as Immediate Past Chairman until the end of 2003. But that was not the end of my National Committee involvement; I was also a member from 2005 to 2009 by dint of also being Regional Vice-President for Australasia of the International Society of Soil Mechanics and Geotechnical Engineering.

I have vivid (if not entirely reliable) memories of a number of incidents that occurred while I was a member of our National Committee.

Probably the most vivid, and on reflection, one of the most amusing for me, occurred when Garry Mostyn was the National Chairman. I have no doubt it would not have been regarded as amusing by the person Garry had in his sights at that time.

The background to this incident includes one of our many unsuccessful bids to host the 4-yearly International Conference on Soil Mechanics and Geotechnical Engineering. My memory of the exact details of the bid are a bit hazy, but I think it was the time Perth put their hat in the ring. Garry may correct me if I've got this part of the story wrong.

Well the particular meeting of the National Committee I refer to was held in a motel quite close to Sydney's International Airport. Present at the meeting were the usual suspects, including an ex-services person who worked for Engineers Australia and was assigned to undertake secretarial work for AGS. One of his important tasks was to pay, on behalf of AGS, the subvention fees to ISSMGE, IAEG, and ISRM. Because we were planning to make a bid for the next ISSMGE Conference, Garry thought it would be a good idea if we rang the Secretary General of ISSMGE to discuss our bid and the bid process, and the entire National Committee should be present. The Secretary General at that time was Dick Parry, who had spent much of his life in Australia and the UK. Dick came on the telephone and it was not long before he relayed the unfortunate news that we (Australia) were behind in paying our fees to ISSMGE and if we did not move quickly we would be ineligible to make a bid because AGS would not be financial.

To say this came as a shock to us all would be an understatement. It was a huge embarrassment for AGS and all present at the meeting, particularly as 'one of our own' had the job of relaying the bad news. Garry Mostyn as chair was definitely not amused. To cut to the chase, he ordered the ex-serviceman/secretary from the room and ordered that he would be taking no further part in the National Committee Meeting. The latter was practically frog marched from the room. I remember this bit of the story vividly and can vouch for its accuracy, because Garry then asked me to take the Minutes for the remainder of that meeting.

Relationships with EA were not always harmonious. In my opinion, much of the problem came down to a number of ineffective, disinterested staff they assigned to our Society to help us conduct our business. Fortunately, matters improved during my time as National Chair, when Val Lee was a huge improvement over past incumbents of the secretary's role.

It was around the turn of the millennium that we became much more professional as a Society. We took over framing and management of our own budgets, although EA still acted as our banker. We increased our membership subscription fees, and what happened? Our membership increased. We developed a constitution, which I well remember, having to deal with the legal firm who helped draft it. I recall the lawyer saying to me when the job was complete: "You now have a Constitution that is superior to those of many countries". I wonder. We also started organising mini-symposia at Chapter level, charging attendees for attendance and finding sponsors for these types of events. I remember one of the first in the Sydney Chapter was on the topic "Computer Methods and Software in Geotechnical Engineering" that was sponsored by Arup and M.A. Coulthard and Associates. It is pleasing to see that the demand for such mini-symposia and extended seminars has not diminished in the interim. These achievements would not have happened without the dedicated, voluntary efforts of a great team of people who make up our Society and its governing bodies.

In my opinion AGS is a wonderful organisation and has evolved in the time since I was National Chair into a mature and very professional outfit. Long may it remain so.

THOUGHTS FROM THE CHAIR

GeoEng 2000

I feel sure that the overwhelming majority of the 700 plus delegates who attended GeoEng2000 in Melbourne in November would agree with me that this was one of the best if not the best geotechnical conference ever held. This claim may be evidence of some hubris on my part, but I can assure you that it is supported by the numerous comments I have received from interstate and international colleagues alike. The difficulty of mounting a multi-disciplinary conference of this type should not be underestimated, bringing together as it did the three major themes of geotechnics and their representative societies, ISSMGE, ISRM and IAEG, as well as a number of other supporting bodies. This conference had something for everyone and a great deal for most. Obviously successes like this do not just happen; they are the result of careful planning and execution. I wish to extend to Max Ervin and the other members of his organizing committee the heartfelt thanks, firstly from the members of your National Committee, and also from the entire Society for a job very well done. Budgeted attendance was exceeded and our expectations of technical and social highlights were surpassed. In all respects this was a most successful conference, and aside from a little back trouble, amongst the most enjoyable I can remember. Well done, and take a bow Max and your wonderful organizing team!

Engineering and Development in Hazardous Terrain

The Management Committee of the New Zealand Geotechnical Society has asked me to pass on their invition to all AGS members to attend their 2001 Symposium (24–25 August 2001) entitled "Engineering and Development in Hazardous Terrain". The symposium will feature invited presentations on recent interesting projects encompassing the investigation, design, risk management, and mitigation for developments subject to:

- river and coastal erosion, deposition, scouring
- slope failures, debris flows, avalanches, rock falls.
- active faulting, earthquake shaking, soil liquefaction
- volcanic activity
- subdivisions, contaminated sites, subsidence, and landfills

Theme sessions will be held over the Friday and Saturday and will be followed by an optional one day field trip on the Sunday. Ample time will be available for social interaction and both formal and informal discussions with colleagues. A trade display featuring latest geotechnical innovations will run concurrently.

Our Kiwi colleagues are keen to have some Australian participation in this important meeting. They would particularly welcome the attendance of somebody who would be willing to provide a briefing on the current status of our own "Guidelines for Hillside Development". Anyone interested and qualified to fulfill this important role, please don't hesitate to contact me (02 9351 2299).

Australian Geomechanics

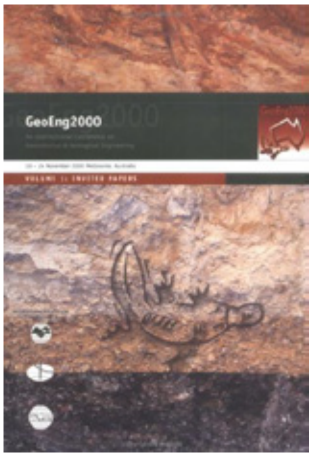
Many of you will know by now that Garry Mostyn's tenure as Editor of this august journal is soon to end. Garry and his family team have provided sterling service for a number of years, and have lifted the standard of this journal by a quantum measure. We have much to thank them for, and indeed on your behalf I shall be offering more formal thanks to Garry on another occasion. In the meantime, we are in need of a new Editor, so I would be most grateful to learn if anyone would be interested in taking on this important role.

Best wishes and adieu!

John Carter

Australian Geomechanics – Dec 2000 5

GeoEng2000: an international conference on geotechnical & geological engineering: 19-24 November 2000, Melbourne Exhibition and Convention Centre, Melbourne, Australia.



2000-2009

THE GATEWAY UPGRADE PROJECT

DR JAY AMERATUNGA

GREG HACKNEY

IAN SHIPWAY

Jay Ameratunga graduated from the University of Ceylon obtained a Master's at AIT, Bangkok followed by a PhD from Monash University in Melbourne. He is a practising engineer and, with over 35 years of experience in geotechnical engineering, Jay has a strong project portfolio that includes major highways, ports and tunnels. He has co-authored about 50 technical papers on soft clay, reclamation and ground improvement. Recently, Springer Publishing Company published his first book on geotechnical engineering titled "Correlations of Soil and Rock Properties in Geotechnical Engineering". Jay is a Past Chair, Queensland Chapter of the AGS, and is a member of the Australian Standards Committee for geosynthetics.

Greg Hackney has over 25 years' experience as a geotechnical consulting engineer working in the civil, transport and mining infrastructure sectors. Greg obtained a degree in civil engineering from UNSW in 1995 and a Master of Engineering Science in 2000. He joined Coffey in 1995, working in Sydney until 2003 when he moved to Coffs Harbour to run Coffey's northern NSW region. In 2007 he moved to Brisbane where he led the Gateway Upgrade Project for Coffey until 2009. In 2015 Greg became a Director of EDG Consulting based in Brisbane and continues in that role working on a wide range of geotechnical projects.

Ian Shipway is an engineering geologist and a Registered Professional Engineer in Queensland and is a Director at EDG Consulting in Brisbane. His geotechnical consulting experience spans more than 30 years. He was a Senior Principal at Coffey up to 2015 where he led the geotechnical design for many major infrastructure projects including the Port of Brisbane Motorway, Gateway Upgrade Project and Northern Access Road to Brisbane Airport. Ian was a member of the committee which developed AS1726-2017 and for the past three years has represented Australia on the ISO Geotechnical Committee and working groups. His current focus is mainly on natural hazards and slope engineering.

Figure 1: Sir Leo Hielscher Bridges

THE FIRST QUEENSLAND "MEGA-PROJECT"

At the time of its construction, the Gateway Upgrade Project (GUP) was the largest bridge and road project in Queensland's history. The signature element of the $1.88B project was the duplication of the 1.63 km Gateway Bridge, with a 300-year design life (a world first). It ranked as the largest balanced cantilever bridge in Australia, and in terms of main span deck area, in the top three internationally.

The project was brought to market and delivered by Queensland Motorways Limited (QML) under a Design and Construct contract, and delivered by the successful tenderer - Leighton Abigroup Joint Venture (LAJV). The civil design was prepared by a joint venture between Aecom and SMEC, and the geotechnical design by Coffey. The design of the duplicated Gateway Bridge involved Cardno and AAS Jakobsen. These parties were the primary proponents responsible for the tender and continued through to detailed design and construction.

The original Gateway Motorway was constructed through numerous stages of work, with the original bridge and major components of the arterial road completed in 1986. Various additional stages of construction were completed through to 1997 to lift the original alignment to motorway standard, and extend it both to the north and south. The GUP provided a duplication of nearly all significant stages of the previous works within a single "mega-project".

Now renamed the Sir Leo Hielscher Bridge – North, the original Gateway Bridge was a Queensland landmark spanning the Brisbane River, which required the proposed duplication running parallel to match visually, while utilizing quite different design elements and construction methods (Figure 1).

In summary, the scope of the project was:

- Construction of a second Gateway Bridge, 5m wider than the first, to meet a client specified 300-year design life. The new bridge included a shared pedestrian/cycle path.
- Refurbishment of the original (existing) Gateway Bridge working under 'live' traffic conditions, within a restricted footprint with extreme access limitations and with complex tie-in works.
- Construction of a new 7 km long, six-lane Motorway north of the Brisbane River (Figure 2) including the construction of 17 elevated structures and bridges along a corridor that required significant geotechnical ground improvement treatment due to extensive deposits of deep soft, Quaternary clay (see Figure 3).
- Upgrading and widening of 16 km of Gateway Motorway south of the Brisbane River involving multiple interchanges; widening existing or new construction of some 15 bridges; and working under 'live' traffic conditions day and night with over 100,000 vehicles per day.

The framework for delivery of the project required LAJV to maintain traffic flows and provide safe passage for motorists, while also minimising the impacts on thousands of neighbouring residents, businesses and sensitive flora and fauna environments.

The authors were all privileged have been involved with the technical aspects of the project and management of the geotechnical team which, at different phases of work, included over 50 engineers and scientists working to deliver the geotechnical design in a close team environment with the civil/structural designers and the contractor.

Figure 2: Airport Interchange on the North Side of the Brisbane River

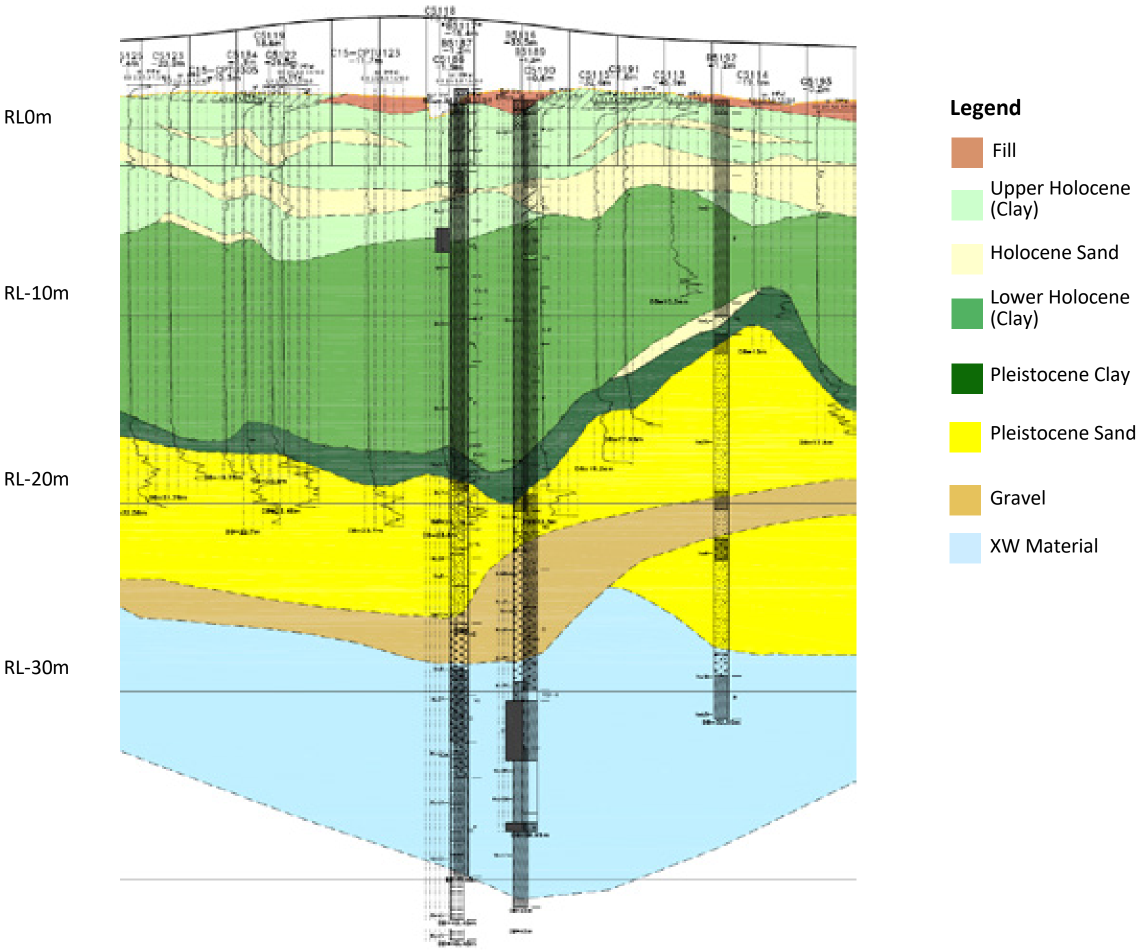


Figure 3: Example of subsurface profile in soft soil areas

GEOTECHNICAL CHALLENGES

Although many aspects of the project required geotechnical input, two of the more significant challenges were the treatment for soft soil deposits and the founding of the Gateway Bridge. Geotechnical input to these issues was considered a major item in both design and construction.

SOFT GROUND ENGINEERING

The alignment was underlain by soft soil deposits up to 30m deep on both sides of the Brisbane River (approximately 7 km to the north and 1km to the south). Figure 3 shows an example of the subsurface profile on the northern side of the Brisbane River.

The importance given to soft ground treatment was exemplified by the broad range of people involved in design and design verification. The design was prepared by engineers and geologists from Coffey, with internal review by Coffey senior staff. The designs were then reviewed by an LAJV appointed team from SMEC, followed by external reviews from the Independent Verifier (SKM with Golder as the proof engineer). Following proof engineering, the designs were submitted to Queensland Main Roads and the Principal, QML, who engaged Connell Wagner (now Aurecon) to provide an independent geotechnical review.

Given the complexity of delivery created by the multiple levels of review and the "four gate" design process, collaboration and coordination by all parties involved in design was essential. Regular discussions to keep parties informed of details and progress assisted in managing delivery and aided in achieving "no surprises" when a report was delivered. Several people were integral to this from the Coffey perspective, including Dayan Jayasekera (Coffey Delivery Manager), Jacob Dunstan (Brisbane Office Manager) and Sukumar Pathmanandavel as a designer / contractor interface. A key role to achieve the successful delivery of this project (due to its nature and sheer size) was played by Jeremy Kruger, LAJV's Geotechnical Manager, who helped to enable optimum geotechnical solutions to be developed.

The major long term residual risk for Queensland Motorways was excessive settlement of pavements built on new embankments over soft soil foundations. To reduce this risk, several initiatives were implemented including:

- Site investigations, targeting test locations critical to soft soil design, especially taking into account specific local geological features along the alignment.
- Non-generic designs appropriate to specific site conditions over short lengths of the alignment taking into account changes in vertical alignment and structures.
- The extensive review process outlined above involving Coffey, SMEC, Queensland Main Roads, Connell Wagner, Aurecon, SKM, and Golder.
- Use of the Observational Approach which included extensive geotechnical instrumentation and continuous back analyses.

In this regard, LAJV demonstrated that the best way of achieving a low risk solution was to follow an extensive testing, design and monitoring regime and construct embankments accordingly. Ground treatments were preferentially designed using preload and surcharge approaches, with options such as rigid inclusions implemented at more critical transition zone areas, such as bridge approaches. Ultimately, many specific geotechnical ground treatments were adopted to manage soft ground issues for the project.

The Gateway Upgrade Project provided soft clay engineering challenges not routinely encountered. Issues that engineers had to deal with included variability in the depth and thickness of the soft soil deposits over short lengths of the alignment due to the presence of narrow paleochannels. The task was compounded by the tight settlement criteria and the imposition of grade change requirements approaching bridge and culvert structures where rapidly changing embankment height itself was a major issue. The GUP team, designers and contractors working together, found and implemented solutions to overcome design issues.

Several types of ground improvement methods were ultimately adopted. For example, at the approaches to structures, ground treatments varied from options that allowed greater post-construction settlement, changing gradually to those that performed more rigidly closer to bridges where larger settlements could not be accommodated. Typically, this meant that the GUP designers adopted conventional preloading without wick drains followed by preloading with wick drains (Figure 4), gradually changing to stiffer techniques such as dynamic replacement and controlled modulus columns, leading to a piled embankment abutting the bridge. Extensive numerical analyses were carried out for the design of overlapping ground treatment methods to provide gradual grade changes to results in a smooth and even pavement surface. The design adopted eight types of ground improvement techniques, to our knowledge, a first in an Australian project. It also involved the biggest ground improvement operation ever to be undertaken at the time in Australia, using:

- 5.8 Mt of imported fill material
- 90,000 m^2 of geotextile fabric
- 33,600 m of octagonal prestressed concrete piles
- 78 km of continuous flight auger piles
- 48 km of displacement auger columns
- 67 km of displacement auger piles
- 58 km of square driven piles
- 1,289 km of wick drains

Some of the more notable aspects and issues relevant to the soft soil engineering included:

- A whole of project approach was adopted for the development of the geotechnical model to provide consistency across the project.
- Embankments on soft ground were designed using standard approaches with close monitoring of settlement, excess pore pressure and lateral movements to achieve stability during construction and monitoring of settlement to inform predictions of post-construction settlement. Monitoring and back-analysis was carried out to refine parameters for use in forward prediction of post-construction settlements. The process of monitoring settlement and back calculating predicted post-construction settlements allowed actions such as additional embankment structures (piles / columns), altered embankment consolidation periods or the use of lightweight fill in the permanent embankment to be implemented where required.
- Coffey, as an integral member of LAJV's design team, used its resources worldwide to assist the project. At its peak, more than 50 geotechnical staff were mobilized when design resources within the industry were very limited due to intense activity levels in the sector.
- LAJV also sought to use design capability within other sections of the design team (SMEC) to provide alternative designs for some bridge abutment transition zones.

Figure 4: Wick drain installation

- The construction phase of the work required a close working relationship between the designers and the construction team. Predictions about timing for ground treatments were fed back to the construction team to allow program review and construction planning. Ground treatments were identified for over 100 discrete areas. These were reviewed and discussed formally on a weekly basis, and informally more frequently. Where construction could not accommodate the timing of ground treatment completion, or where the soft soil conditions were not in line with the design
- Assumptions, changes to the design were implemented.

THE NEW GATEWAY BRIDGE

The new Gateway Bridge (NGB) was the iconic element of the project. From tender to the detailed design stage, the geotechnical design of the NGB was conducted by Professor Ian Johnston and reviewed by Professor Harry Poulos, before being handed to Rob Day assisted by Daiquan Yang in the detailed design phase.

The NGB is a duplication of one of Australia's largest bridges. It offsets the existing bridge by about 50 m and visually mirrors the existing bridge in appearance but was widened to accommodate pedestrian and cycle pathways.

The bridge is about 1.6 km long and spans the Brisbane River and a portion of the adjacent floodplain on the northern side. Figure 5 shows the longitudinal section and simplified subsurface profile along the length of the bridge.

The geology on the southern side of the river is dominated by Triassic aged siltstone, sandstone and coal of the Aspley-Tingalpa Formation which is encountered at ground surface level. On the northern side rock is significantly deeper, encountered at around 25 to 30 m below sea level.

Although detailed investigations were carried out for the proposed bridge, all available information from the existing bridge design (Williams, 1989) and construction was used. LAJV consulted those involved in the original bridge construction, most of whom were retired, to identify and understand potential issues. This information allowed LAJV to take decisions that would ease construction at the site. The central span (260 m long) was supported on piers located towards the edges of the river, which are founded on piles embedded in rock. Footings between the southern abutment and the south main pier comprised shallow footings, with driven piles adopted for the approach to the northern main pier.

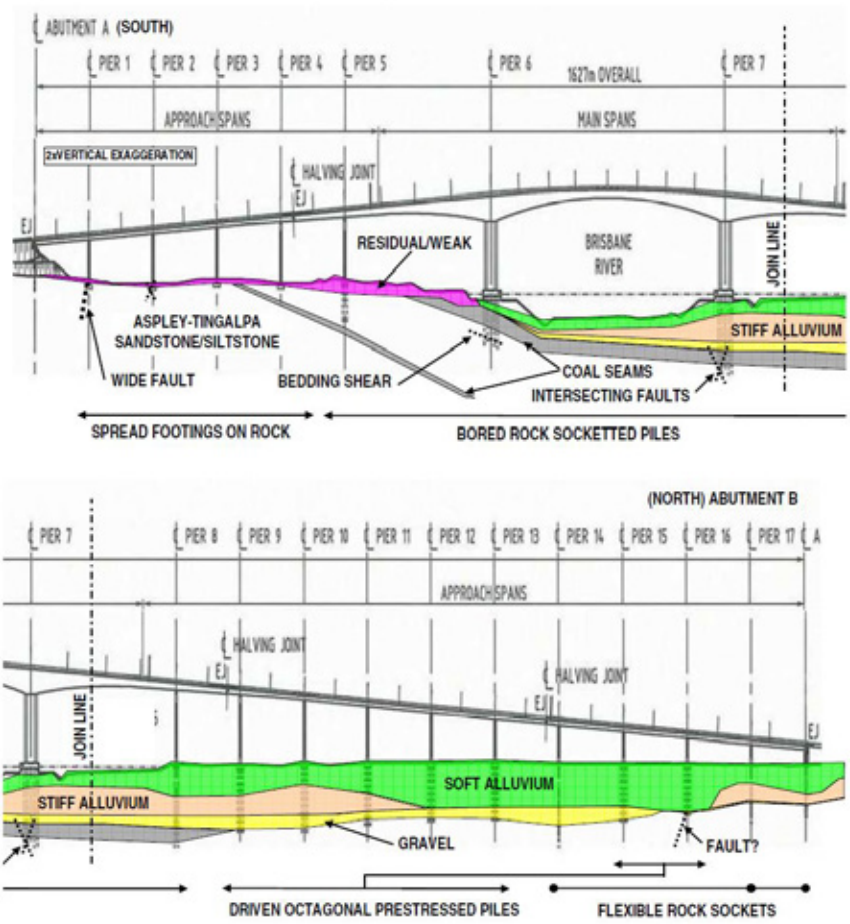


Figure 5: Long section along the length of the New Gateway Bridge

2000-2009

Some of the differences in footings and foundations for the NGB compared to the existing bridge included:

1. Groups of large diameter vertical piles with longer rock sockets (NGB) rather than groups of smaller diameter raked and belled piles for the existing bridge.
2. The base and rock sockets of piles on the southern pier of the existing bridge (belled below the toe of the permanent casing to between 2.2 m and 3.0 m in diameter) was visually assessed by personnel down the pile hole. Although the specification for the new bridge required physical inspection of the borehole excavation, LAJV with technical input from the design team convinced the QML and Queensland Main Roads to move away from this practice due to latest occupational health and safety practices. To alleviate the concerns, several additional requirements were implemented including: a) inspection using a special down-hole camera in an open ended diving bell (SID), b) axial load tests of two test piles and two production piles using Osterberg cells, c) continuous cored boreholes at each pile location at the main pier locations.

Construction of the main piers (Figure 6) located within the Brisbane River channel was particularly complex due to the need for access for the heavy machinery and the presence of the weak, highly compressible estuarine clay with the potential to affect settlement and stability. The existing bridge had been constructed using a floating plant and a piled causeway (Day et al., 2012). For the NGB, a rockfill causeway was constructed on the northern side. Although high strength geotextiles were used, placement of rockfill initially led to mud waves on the sides and in the front as the causeway was advanced from land. As the northern main pier was located close to the shipping channel the risk of failure was assessed to be high if the mud waving to remove the soft soil was adopted, and therefore at this location, dredging was carried out to remove the weak soils. For the southern side, mud waving was used to displace the soft soil and alleviate associated issues. To provide confidence in the stability of the platform under expected loading from the machinery and stockpiles the platform was subjected to an equivalent surcharge load.

ACKNOWLEDGEMENTS

We wish to acknowledge all engineers, geologists, technical officers and other staff of Coffey who contributed to this project. Special thanks are also due to members from the other design consultants and LAJV.

Coffey used its extensive network throughout Australia and overseas to deliver this project. Significant inputs were provided by Coffey Principals and Senior Principals including Prof. Ian Johnston (NGB) and Rob Day (NGB), Weeks White (pavements), Kim Chan, Patrick Wong, Beng Cheah (soft ground and other geotechnical), Ian Shipway (ground model), Prof. Harry Poulos (NGB, soft ground and other geotechnical), Garth Powell (construction aspects), Chris Bridges (retaining walls and temporary works), Greg Hackney (general geotechnical), Beng Cheah and David Barker (bridges and pavements). Specialist input was also provided by Prof. John Atkinson and Ian Webber from the UK, Marc Woodford.

Considering there were more than 50 geotechnical engineers and geologists working with the contractor, civil designer, reviewers and various other consultants a management structure was in place to cater for all the needs. Ian Shipway was the Project Director from the initial tender stage to part way through design, when Greg Hackney assumed the role. Jay Ameratunga was the Geotechnical Team Leader for the tender phase and preliminary design stages. The Team Leader role was also filled by Greg Hackney during the remainder of the detailed design stage and throughout construction, with Beng Cheah and Thayalan Nall overseeing the delivery of the final designs and assessment during construction.

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Figure 6: Construction of the New Gateway Bridge

2000-2009

ANDREW LEVENTHAL AM CHAIR 2002-03

It was my privilege to be the National Chairman of our Society for a term covering 2002 and 2003.

AGS is recognised by Engineers Australia as the most active of its Technical Societies. This is not only through the size of its membership, but importantly through the activities of that membership. AGS is a Society that is "run by its members, as volunteers, for its members". That has been, as I recognise it, its mantra from inception.

Accordingly, and not surprisingly, AGS is recognised for its on-going contribution to civil engineering in Australia, with issues such as the development of rockmass quality assessment initiated in Sydney Chapter in 1978 with the symposium on "Design Loadings for Foundations on Shale and Sandstone in the Sydney Region" (Pells et al, 1978) being a forerunner to the guidelines published in 1998, and the variations on them up to and including a review in 2019 (Pells et al, 2019). I have no fear that this is discussed in more detail by others.

I feel very fortunate as a student to have experienced lectures from both Ted Davis and Harry Poulos, as well as John Booker, and am forever in their debt for having the opportunity to learn from these for being leading lights in geomechanics practice in Australia. It was in this setting that my interest in geomechanics was forged, as I am sure is the case for many others. Their presence in geomechanics contributed to the success of AGS, and their interest and drive in the advancement of geomechanics research and therefore practice.

I contend that this philosophy is one that AGS has continued throughout its 50 years, with local chapter seminars advancing the science, national conferences held jointly with NZGS, and with major international conferences.

This latter includes such as GeoEng2000 wherein AGS demonstrated to the Three International Sister Societies the value of the combination of ISSMGE, ISRM and IAEG in one conference, at one venue – held under the masterful overwatch and guidance of Max Ervin (thank you, Sir).

> There's always that issue of the colloquial usage of "risk" which is in most cases not technically correct unless likelihood and consequence are appraised.

Before that, I am aware of an ISRM International Conference, and of course, under the leadership of John Carter, AGS is hosting the 20th ISSMGE International Conference in Sydney in September 2021. [Be there!!]

This philosophy of "advancing the science" continued strongly in the 1990's and into the first decade of the millennium. In the period that covered my term as National Chair, I believe that the major contribution made by our Society under my watch to the Nation was the continuation of the introduction of Landslide Risk Management into Australia. This is also recognised to have led the World in the introduction of LRM.

LANDSLIDE RISK MANAGEMENT

I have been reliably informed that AGS (1985) – as I call it, and I do so with sincere apologies to Bruce Walker – wherein was made the introduction of the concept of landslide "risk" internationally, and particularly in the residential sub-division context.

AGS (1985) - again with apologies to Bruce Walker, but this citation style fits well with the later rationale of the citations adopted for AGS (2000) and AGS (2007) wherein the individual authors were acknowledged, but the papers had a generic citation identification – was a very brief technical paper published in what is now known as our Journal, *Australian Geomechanics*. However, albeit as brief as it was (2 pages of text, 2 full page diagrams, and 3 pages of tables), it produced a huge advance in the concept that the word "stable" was no longer appropriate. The word "stable" held issues of its absolute nature, in that a slope was "stable", and once determined so would remain so 'for ever and a day' or was "unstable". Both of these acted as absolute terms. This provided an open door for 'our very good friends' in the legal profession, one could suggest. This was the driving idea – to introduce the concept that black-and-white determinations of stability were impractical philosophically, and were pragmatically challenging initially to the presentation of AGS (2000) as a major revision of AGS (1985) in terms of the advances of Risk Management in the engineering community in the intervening 15 years.

The Society is in the debt of Bruce Walker and Robin Fell, both of whose untiring enthusiasm to advance LRM led initially to the presentation of AGS (2000) as a major revision of AGS (1985) in terms of the advances of Risk Management in the engineering community in the intervening 15 years.

The revision was considered necessary because of these external advances in the early 1990s – such as the development of the Australian Standard for risk management, AS/NZS 4360 (2004). The Thredbo Landslide, which unfortunately took 18 lives on 30 July 1997, was an impetus to the volunteers to complete what was a 7 year task. With my encouragement, John Carter provided a copy of the "hot off the presses" guideline to Coroner Hand on the last day of sitting of his enquiry into the deaths caused by the landslide – which remains the landslide of greatest fatalities in the nation's history. In his report, Coroner Hand recommended "*that the Building Code of Australia and any local code dealing with planning, development and building approval procedures, be reviewed and, if necessary, amended to include directions which require relevant consent authorities to take into account and to consider the application of proper hillside building practices and geotechnical considerations when assessing and planning urban communities in hillside environments. I further recommend that the report on Landslide Risk Management Concepts and Guidelines* [aka AGS 2000] *be taken into account in undertaking this exercise*" (Hand, 2000 - refer to Paragraphs 917 to 920).

In light of the Coroner's strong recommendations, and the wide publicity associated with his findings, a Risky Roadshow was held throughout the nation in 2002 to explain the guidelines to authorities and practitioners. This was successfully held in each capital city, as well as Wollongong and Newcastle, with 365 attendees. Sponsorship was provided by Emergency Management Australia. A hard copy of the paper was provided to each Local Government Area in Australia.

In 2006, the authors of AGS (2000) felt that AGS (2000) had some issues that should be addressed and also would benefit from additional explanations. This led to the formation of The Landslide Taskforce, which developed the five technical papers that collectively form AGS (2007). As for AGS (1985) and AGS (2000), this too was published in the Society's Journal, *Australian Geomechanics*. A copy of the suite of papers was provided on CD to each Local Government Area in Australia.

AGS (2007) was recognised by Engineers Australia Civil College through the award of the Warren Medal, its prestigious award for published papers in 2007. The presentation of the Award was made at a Sydney Division Fellows Lunch in NSW Parliament House. (Unfortunately, Robin Fell was unable to attend the presentation.)

Another Risky Roadshow followed in 2011, and again was held in each capital city, and Wollongong and Newcastle. The Roadshow attracted 480 attendees throughout the nation.

With funding support from the Australian Government's National Disaster Mitigation Program, an Education Empowerment website for LRM was developed, and with the support of the Sydney Coastal Council Group, was launched in 2012. This empowerment website is linked from the AGS website, and provides guidance, testing and copies of the technical papers.

Our LRM activities also won Highly Commended awards from the Attorney General's Department in 2008 and 2013 under the Australian Safer Communities awards for projects of national significance. Our activities were conveyed to the international community in 2006 at a Landslide Risk Management workshop in Barcelona 2006, and in 2007 in Hong Kong at an international Landslide Disaster Management Forum.

NDMP Landslide Taskforce at their Workshop held in Sydney on 21 September 2005

(L to R) Andrew Leventhal (chair), Angus Gordon, Arthur Love, Robin Fell (Hazard Zoning working group convenor), Grahame Wilson, Fiona MacGregor, Ralph Rallings, Max Ervin, John Braybrooke, Grant Murray, Warwick Davies, Peter Tobin, Alex Litwinowicz, Ian Stewart, Mark Eggers, Greg Kotze, Garry Mostyn, Garth Powell, Tony Phillips (Slope Management working group convenor), Bruce Walker (Practice Note convenor), Tony Miner, Graham Whitt, Geoff Withycombe (Sydney Coastal Councils Group), Henk Buys

Celebrating the award of the 2007 Warren Medal to the Landslide Taskforce at NSW Parliament House on 28 March 2008 were: (L to R) Peter Godfrey (Engineers Australia National Deputy President who, up until now, was Civil College representative on the AGS National Committee); Richard Barnes (Engineers Australia Sydney Division President); Andrew Leventhal (chair of Landslide Taskforce Steering Committee); Brian O'Donnell (Chair of the Board of the College of Civil Engineering of Engineers Australia); Bruce Walker (Warren Medal recipient – convenor and principal author of the Practice Note Guideline 2007); Tony Phillips (Warren Medal recipient – convenor and principal author of the Australian GeoGuides); and Geoff Withycombe (Regional Coastal Environment Officer / Executive Officer, Sydney Coastal Councils Group, sponsor for the NDMP LRM project).

The Landslide Taskforce believes that virtually every Local Government Area across the nation has landslide hazards of one form or the other. Whilst AGS (2007) is yet to be referenced in State planning documents (that remains a task that is outstanding), it is referenced in a guideline document that accompanies the Building Code of Australia. AGS (2007) is widely referenced in planning documents of many (of the informed) Local Government Areas.

Amongst the many, it is important to recognise the particular contribution of the convenors of the Working Groups in this current task, who were responsible as principle authors for the Guideline documents developed under the NDMP Landslide Taskforce:

- Robin Fell (Landslide Zoning) – see also Fell (2005);
- Bruce Walker (Practice Note) and
- Tony Phillips (GeoGuides).

In addition, Colin Mazengarb (Department of Mines, Tasmanian) has been a shining light in the manner to which government assistance in susceptibility mapping can assist the identification of landslide hazards throughout widespread landslide prone areas. The work of Phil Flentje is also to be recognised in the Wollongong / Illawarra Escarpment area for the similar high-quality mapping and monitoring of landslides.

RELATIONSHIP WITH ENGINEERS AUSTRALIA

AGS is recognised by Engineers Australia as its most active Society. To further the value of the relationship with Engineers Australia, the Sydney Chapter decided to nominate a representative to the Division Committee, for which I apparently nominated. One outcome of that was my appointment as Division President (for two consecutive terms) at a time of challenge between the National Office of Engineers Australia and the Divisions.

A couple of outcomes:

1. The recognition that delivery of Continuing Professional Development across Engineers Australia was not being "measured" – and hence the introduction of reporting by the Chapters to the National Committee of CPD activities and attendances, so that an AGS - wide measure could be maintained;
2. For my troubles, I was instrumental in justifying the introduction of the *every-day* name of "Engineers Australia" for "The Institution of Engineers Australia" as exists today.

A FEW QUESTIONS TO END

Q1: Did the members of our Society beneficially improve the understanding of rockmass quality in the Sydney region?

A1: "Yes" we did, to the extent that the methodology has been used not only throughout the Sydney region and Sydney Basin, but throughout the nation.

Q2: Did members of our Society recognise an issue in Landslide Risk Management, develop techniques and guidelines to provide regulators, practitioners and the general public with means to understand the issue, and thereby to be forewarned, and hence forearmed, and enhance the methodology three times over a period in excess of 2 decades?

A2: "Yes" we did, and are recognised internationally as leaders in this task.

Q3: Is there more to do?

A3: There are, unfortunately, many operators who practice outside their area of competence in LRA/LRM who have not taken advantage of the guidelines and commentaries, Roadshows and other means of empowerment that our Society has developed and made freely available. They means are available to become competent practitioners with a small degree of Continuing Professional Development. [..as he steps down from the soap box.]

Q4: Does our Society provide material and guidelines to assist learning by our members?

A4: "Yes" it does, very definitely, courtesy of the professional contribution of our members as volunteers.

Q5: What does membership of the National Committee offer to members?

A5: Apart from contributing to our Society, one of the intangible advantages of membership of the National Committee is the opportunity to meet senior members of the profession about the nation. Not to be missed.

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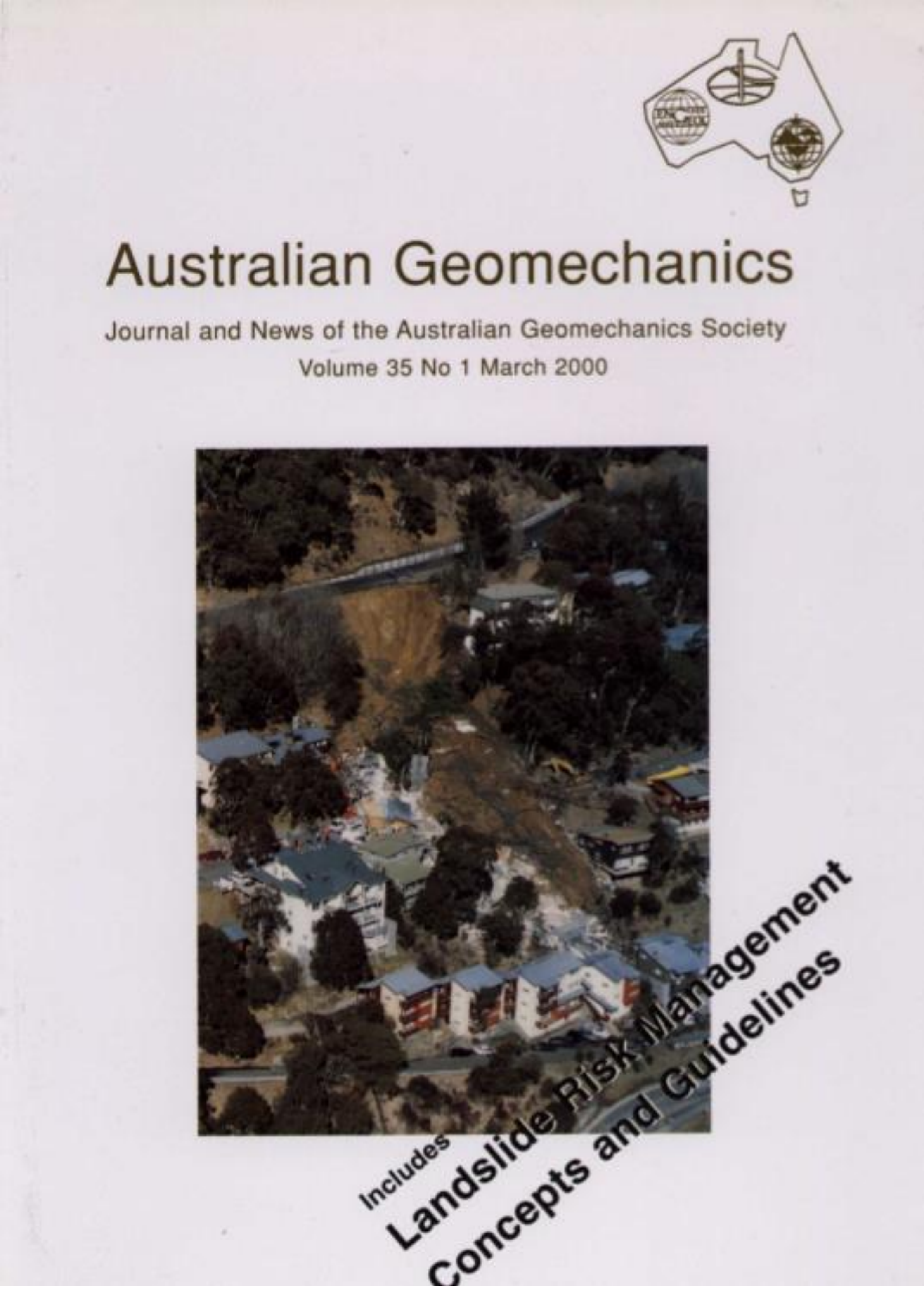
Australian Geomechanics
Journal and News of the Australian Geomechanics Society
Volume 35 No 1 March 2000
Includes
Landslide Risk Management
Concepts and Guidelines

2000-2009

SEA CLIFF BRIDGE – MAKING A COASTAL ROAD SAFER

ROBERT WILSON

MICHAEL NORMAN

ALAN MOON

Robert Wilson is a Senior Principal with Coffey. He graduated from the University of Otago with an Honours degree in Applied Geology. He has been with Coffey for over 30 years and has worked on road, railway, pipeline, building, bridge, tunnel and slope instability projects throughout southeast Australia, and beyond. He has expertise in ground models, site investigations, route alignment studies, risk and slope instability.

Michael Norman is a Principal Geotechnical Engineer with Coffey and Operations Manager for New South Wales. He has a Civil Engineering degree from Northwestern University in Chicago and a Master of Engineering Science from Sydney University. He spent 8 years designing dams and working in mining infrastructure projects before joining Coffey. Mike was Geotechnical Team Leader and member of the Alliance Management Team for the Lawrence Hargrave Drive Project and subsequently he had senior roles on 4 more alliances in Australia. Between 2009 and 2017 he worked for Coffey in Canada and New Zealand before returning to Sydney.

Alan Moon has an Honours degree in Geology from Imperial College, University of London (1970) and a Masters degree for research in Slope Stability from the University of Tasmania (1985). Working as an engineering geologist, Alan has provided specialist technical and review input into dams, tunnels, roads and other infrastructure projects in Australia and overseas. Alan has contributed to national and international publications on landslide risk assessment and management.

1 A HISTORY OF LANDSLIDES

The Sea Cliff Bridge is located between Coalcliff and Clifton on Lawrence Hargrave Drive, which is the coastal road that extends north from Wollongong to Sydney. The bridge was built to address a road safety issue; but it has become a tourist destination drawing about 10,000 visitors to the region annually. It has been used in many television commercials, and it even features in a video game.

Lawrence Hargrave Drive was constructed in 1878. The 1350m section of the road between Coalcliff and Clifton is located near the base of a coastal escarpment rising 300m above the road (Figure 1). Aggressive marine erosion is taking place at the base of the cliffs causing undercutting of the cliffs and as a result the road has had a long history of severe embankment instability, rock fall and debris flow problems (Hendrickx et al., 2011).

Following the Thredbo Landslide in 1997 and a change in slope risk management policy by the Road Traffic Authority (RTA, now part of Roads & Maritime Services), a detailed risk assessment and remediation work program commenced at the site (RTA 1998, GHD-Longmac 2002, URS Australia 2003).

This work rated the site as the highest for slope instability risk to roads in NSW and it led to an 8-week road closure for remediation works starting in July 2002. In November 2002 a "rain" road closure protocol enforced by "boom gates" commenced. The protocol required the road to be closed following 35 millimetres of rain, of which there were 10 closures in the following 8 months. In July 2003 rock falls near workmen during dry weather and a developing embankment failure led the RTA to close the road indefinitely. On 29 August 2003, the NSW Government announced that it was to embark on a major project to upgrade the road, with the work expected to take 2½ years and cost $40 million. A 2½ year closure was bad news to businesses along the coast that relied on through traffic and tourists.

This paper outlines the project geology and landslide hazards and landslide process rates. It discusses how Quantitative Risk Assessment was used to assist option engineering to meet risk targets. The paper goes on to outline geotechnical issues related to bridge design and the hazard mitigation measures for non-bridge sectors.

Figure 1: 1967 view of the site looking south. Wollongong lies in the distance
Photo courtesy of RTA photo archive.

2 ALLIANCE DELIVERY, MULTI-CRITERIA ANALYSIS AND ARL3

The RTA chose to use an alliance delivery model for the project – the first alliance for the RTA. In mid-November 2003 the RTA decided to team with Barclay Mowlem (civil contractors), Maunsell Pty Ltd (consulting engineers) and Coffey Geosciences Pty Ltd .

The first task of the Alliance was to develop criteria for selecting the preferred design. A multi-criteria analysis was adopted to select the preferred design option based on the following criteria:

- Road User Landslide Risk – road re-opened with an assessed risk of ARL3 or lower (see below).
- Economic – construction cost and anticipated maintenance costs (Adjusted Target Cost $48m)
- Schedule – Open to traffic by end of Feb 2006
- Safety – Zero lost time injuries
- As well as key Environmental, Community and Stakeholder targets.

The landslide risk ARL3 criterion relates to the Assessed Risk Level (ARL) levels defined in the RTA "Guide to Slope Risk Analysis" (Stewart et al. 2002) and it applied to the sum of all the slope risks to life along the project, not just the slope risks at individual locations.

There are five ARL levels ranging from ARL1 (highest risk level) to ARL5 (lowest risk level), and for which ARL3 roughly equates to an annual probability of death of about 10^{-5}.

The ARL rating for the road prior to remediation was ARL1 and the risk to life was assessed to be higher than 10^{-2}.

3 GEOLOGY AND LANDSLIDES

3.1 Geological setting

Over the closed section of the road the coastline comprises two prominent bays (amphitheatres) and three headlands. These features were used to subdivide the site into five geotechnical domains (Figure 2):

- GD1 – Southern Headland
- GD2 – Southern Amphitheatre
- GD3 – Middle Headland
- GD4 – Northern Amphitheatre
- GD5 – Northern Headland

The bedrock geology comprises sandstone and claystone units of Permian to Triassic age that generally dip between 0° and 5° to the northwest (i.e. obliquely inland), and which are underlain close to sea-level by the 3m thick Bulli Coal Seam. The sandstone units within the succession form prominent, sub-vertical cliffs, whilst the claystones form the intervening slopes (Figure 3).

Superficial deposits of colluvium derived mainly from debris flows and rock falls mantle the lower angled claystone slopes, and form fan-shaped deposits up to 40m thick in the two amphitheatres (GD2 and GD4).

Whilst most landslides are triggered by intense rainfall, the slope processes are fundamentally caused by marine erosion that is oversteepening the slopes below the escarpment (Hendrickx et al., 2011). Marine erosion is removing the Bulli Coal Seam, which leads to toppling failures of the overlying Coalcliff Sandstone.

This in turn leads to oversteepening of the overlying Wombarra Claystone that fails by debris flows and debris slides. The process is repeated up the slope to the Hawkesbury Sandstone forming the cliffs at the crest of the escarpment. The processes are further driven by differential erosion and undercutting of the claystone intervals, and these lead to rock falls from the sandstone units.

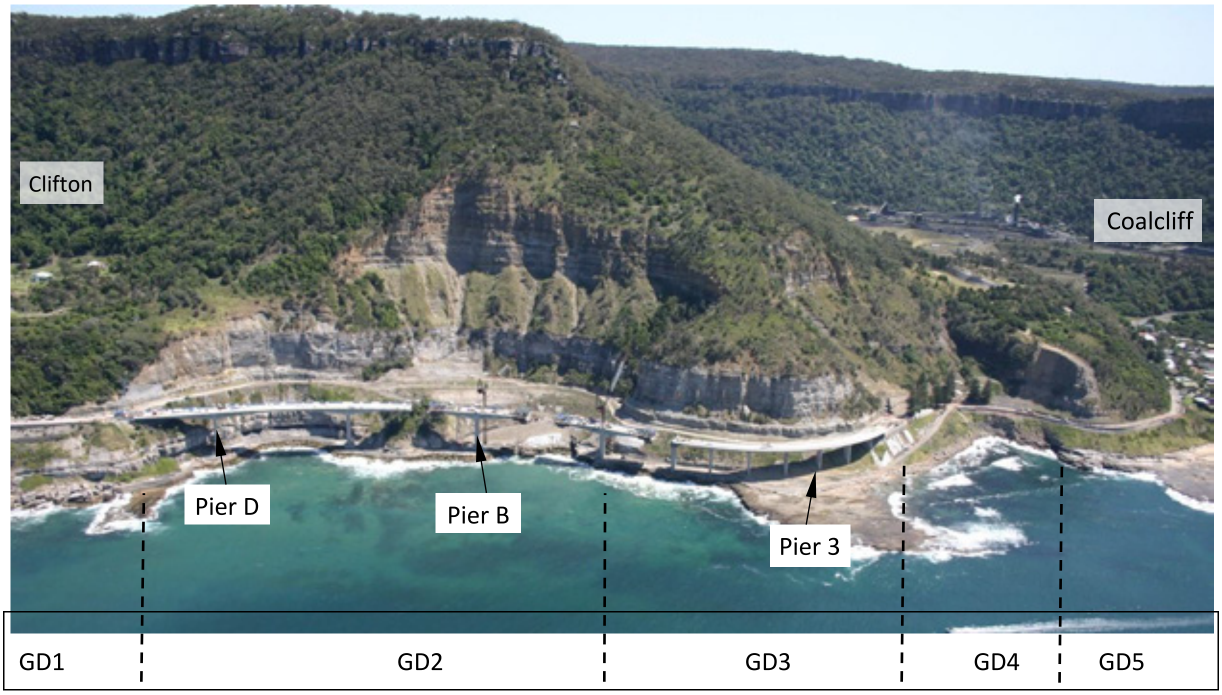

Figure 2: View of entire project. Photo courtesy of RTA

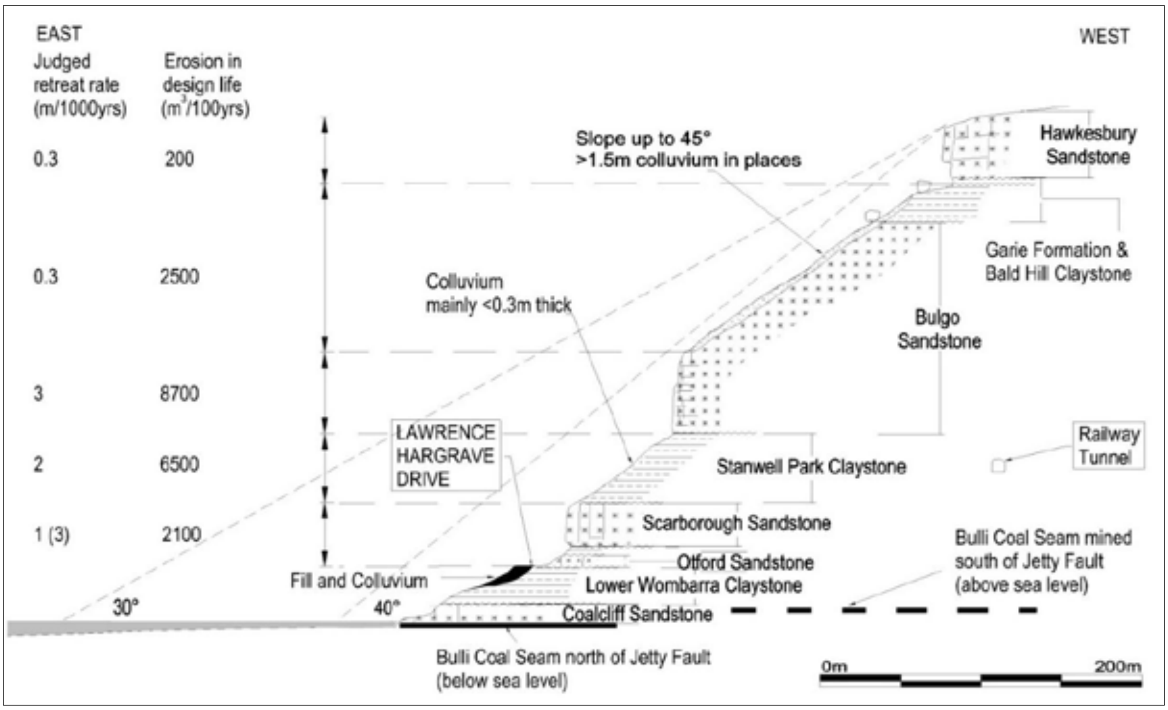

Figure 3: Geological Section showing judged slope retreat rates and erosion in design life for each slope unit

3.2 Landslides affecting people and vehicles

More than 103 landslide events are known to have occurred at the site between 1913 and 2002 (Hendrickx et al., 2011). Many of these were complex events involving multiple landslides with various modes of failure. For example, the 1950 event involved numerous debris flows, rock falls, embankment failures and retaining wall failures.

Twelve landslides are known to have interacted with vehicles or people as listed below. RTA experience suggests many other incidents have gone unreported.

- Direct impacts of rocks with cars in GD2 or GD3 (x 6) (Figure 4),
- Cars running into rocks (x 2),
- A motorcycle hitting a small rock on the road (x1),
- A car plunging off the road into the ocean due a developing embankment failure in GD3 resulting in the death of the driver (x1),
- Cars being stopped by debris on the road and then being subsequently hit by a falling rock (x2).

The construction records, albeit incomplete, indicate about $25 million (2003 equivalent) were spent on repairs and slope mitigation works between 1941 and 2003. In places the road resembled a museum of slope remediation measures.

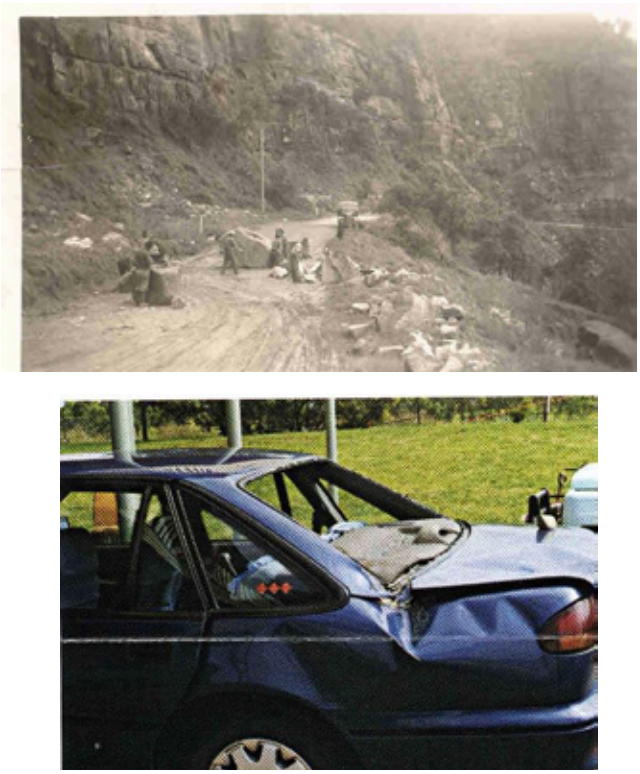

Figure 4: Rock falls in GD2
Photos courtesy of RTA photo archive

3.3 Predicting the size and frequency of landslides

In landslide risk assessment, the most important question is "what might happen in the future?" Records of past landslides can provide some information on what has happened but are invariably incomplete. Slope models that answer questions such as how the slope formed, how fast it is eroding, what proportion of the erosion is caused by landslides, and what is the size-frequency distribution of the landslides can be used to support judgements about what might happen which go beyond the limitations of the historical record. Although slope models provide simplified views of reality, they enable prediction and they can be tested and updated with local and regional knowledge and relevant knowledge from elsewhere.

"Landslide size-frequency models", based on procedures described in Moon et al (2005) were developed for the Lawrence Hargrave Drive project for each of the seven slope units above the road. The models, which presented judgements on the type, frequency and volume of future landslides, were based on knowledge and interpretation of evidence on the:

- Known landslides referred to in Section 3.1 and 3.2;
- Geological history of the region;
- Other landsides in the Wollongong area (including rock falls, debris flows and debris slides);
- Cliff retreat rates in the region and elsewhere;
- Rock falls in the catch ditch in GD2 after July 2003, and rock falls and debris flows during the design period;
- Landslide failure mechanisms including travel distances.

Wilson et al (2005) show all seven "landslide size-frequency models" used on the project and Moon et al (2005) present and discuss four of the models in more detail.

The "landslide size-frequency models" developed for this project assessed that, without preventive measures, a long-term average of about 200 m^3 of slope debris would land on or cross the existing road each year. Most of the landslide debris would be associated with rock falls or debris flows and much of the debris reaching the road would be very small (i.e. volumes of less than one cubic metre).

3.4 Quantitative Risk Assessment, QRA

A QRA approach using the "landslide size-frequency models" was used to review the slope risks associated with the existing road, to assess the effectiveness of the proposed engineering works, and to assist in the assessment of future maintenance requirements and road closures.

The QRA approach is described in Wilson et al, (2005).

The risks to road users were calculated using formulae adapted from Bunce et al (1997) in an Excel workbook composed of 59 linked spreadsheets. Multiple spreadsheets were used to address over 3000 combinations of judgements that were sourced from the 5 geotechnical domains; up to 6 geological units in each domain; several different failure mechanisms and rock fall and debris trajectories; 6 to 8 size categories for each analysis; differing vulnerabilities; with and without remediation for differing road alignment options. The four key cases considered were:

Cases	Annual risk to life	ARL rating
Case A: Before mid-2002 without any remedial works	1 in 10 (1 x 10^{-1})	ARL1
Case B: In 2003 with upgraded catch ditches and rockfall fences	1 in 17 (6 x 10^{-2})	ARL1
Case C: With bridges only	1 in 125 (8 x 10^{-3})	ARL1
Case D: With all works in all geotechnical domains	1 in 250,000 (4 x 10^{-6})	ARL3

The risk profiles with limited mitigation (Cases A and B) were dominated by a few risky hazards at several locations. As the risky hazards were eliminated in the analyses of potential remedial measures (i.e. Case C), the risk profile shifted to a more uniform pattern that included lesser risks at many locations. The calculated risk for Case A is comparable with the history of the site, which suggests only one death potentially attributable to landsliding and several close calls (see Section 3.2). The calculated risks for Cases A and B are comparable with those assessed by others (RTA 1998, GHD-Longmac 2002, URS Australia 2003) for the same road conditions but using differing assumptions.

Benefits and learnings of using QRA on the project include:

- QRA was a geotechnical tool used in conjunction with conventional slope analysis methods, which in the study included rock fall, rock toppling, debris flow, and circular and planar sliding slope modelling and analyses.
- QRA was an indispensable tool to address the multiple hazards and multiple consequences onsite because it provided a structured framework for collecting and presenting information, and making risk decisions. And it allowed the component parts of the QRA to be explicitly stated and reviewed.
- Many simplifications had to be made when conducting the QRA given the inherent complexities of landslide behaviour and their resulting interactions with persons, vehicles and structures. Based on preliminary work conducted as part of this study it was judged that the simplifications would produce second order variations in the assessment of the total risk if they were specifically addressed and would not significantly affect the identification and ranking of the major risks.

4 OPTION ENGINEERING AND AVOIDING PART OF THE PROBLEM WITH TWO BRIDGES

The approach to the design of risk mitigation measures was to identify and quantify slope hazards as early as possible in the project so that everybody understood the hazards, where the major risks were likely to be, and options to reduce and manage the risk could be developed. The full quantitative risk assessment (QRA) discussed in Section 3.4 was carried out in parallel with the detailed design of the selected options because of time pressures on the project.

It quickly became apparent that the slope risks to life in the Southern Amphitheatre (GD2) and Middle Headland (GD3) were such that avoidance was the only option for these locations. In late November 2003, workshops were held with the community to canvasses options for the road and more than 70 options were put on the table. These options included various combinations of bridges, tunnels, avalanche shelters and other structures. By January 2004, the options were reduced to 4 which were presented to the community for feedback (RTA, 2004).

The adopted design comprises conjoined bridges through GD1 to GD3, together hazard mitigation measures elsewhere (including locally to help protect the bridge piers).

5 BRIDGE DESIGN ISSUES

5.1 Design of bridges

The southern bridge consists of a 5 span 448m long cast in-situ balanced cantilever bridge that extends from the Southern Headland (GD1) through the Southern Amphitheatre (GD2). The foundations for each pier consist of six 1.5m diameter, 15m long bored piles, socketed into rock beneath the Bulli Coal Seam (Figure 5). The piles support 12x9x2.5m pile caps and the piers are 6.5m by 2.8m in section.

The northern bridge consists of a 7 span 203m long incrementally launched bridge that extends from the southern end of GD4 around the Middle Headland (GD3). It includes 7 piers which range in height from 8.1m to 20.4m. Three piers are constructed on bored piles that range in length from 9 to 17m and are socketed into sandstone rock. Four piers are supported on spread footings.

The detailed geometry of the bridges was based on rockfall clearances, accessible pier locations on the rock platforms, road geometry requirements, and aesthetic considerations.

5.2 Piers exposed to rockfall

Whilst the bridge decks are located above potential impact zones, the piers were potentially exposed to rock falls and/or large debris flows. For each pier, the hazards were assessed, and design boulder sizes and impact loads were assessed based on the site geometry (e.g. distance of pier from the cliff), the potential for break-up in transit, and the results of extensive rockfall and debris flow analyses.

For most piers design boulder sizes of 5 to 10 tonnes were adopted, which gave impact loads in the range 3 to 22MN. For Pier B in GD2, a design boulder size of 120 tonnes was adopted, which gave an impact load of about 22 MN. The calculated loads on the piers were within the design capabilities of the piers. Irrespective, given the piers are critical infrastructure elements, protection was provided for all piers.

Existing roadside features were kept where they contributed to the protection, including the existing catch ditches, rock berms, guardrails, and the low height rock fence in GD1. In addition, various combinations of gabion walls, earth deflection bunds, stacked rock protection and ripping of the road surface (to reduce rock bounce) were applied along the old road to provide protection and/or deflection barriers as required. Other works included local dowelling of the cliffs above Pier D and Piers 1 to 3 to lessen the potential for rock slab failures.

5.3 Southern Abutment and historical mining

The southern abutment of the southern bridge is located over a zone of historic coal mining dating back to the late 1800s. The worked coal seam is the Bulli Seam; and the roof and floor of the workings consist of medium strength siltstone and sandstone.

Three main adits, trending west (inland) from the coastline, underlie the Southern Abutment site. A fourth adit and a ventilation adit and a vent shaft (with furnace) lie nearby. Historical evidence indicated the main adit was 3m wide and 2m high, and it was constructed in tandem with the parallel ventilation adit that was 2m by 2m square. In 1980, following detection of methane in the workings, concrete plugs were placed in the entrance of each old adits to prevent access. These concrete plugs prevented to access to assess the present stability of the workings.

It is unknown how much historical mining subsidence, if any, has taken place.

Irrespective, the mining had created large voids in the vicinity of the Southern Abutment, and these voids needed to be addressed in the design. Loads for the Southern Abutment are in the order of 6000kN and settlements needed to be kept below 5mm due to structural constraints. The adopted foundation comprises a raft foundation that was designed to span a 5-metre diameter void collapse at depth.

Figure 5: Drilling of a bored pile for Pier C in GD3 Photo courtesy of RTA

5.4 Bridge piers – foundations

The pile foundations for the piers were analysed using the computer program DEFPIG (Poulos, 1990). DEFPIG is a linear-elastic finite element package that calculates loads and deflections for pile groups.

The pier loading data were provided as multiple serviceability and ultimate load cases for each pier. The loading data for the piled foundation for the North Abutment of the northern bridge also included two bridge launching load cases.

The piled foundations for the casting yard in GD4 were analysed using the computer program PIGS (Poulos, 2002). PIGS is a program that calculates vertical deflection of piles accounting for the induced settlement due to interaction with nearby piles.

6 HAZARD MITIGATION MEASURES FOR NON BRIDGE SECTORS

These measures were essential because the assessed risks were still ARL1 with the bridges alone (see Case C in Section 3.4).

6.1 GD1 - adjacent to the Southern Abutment

The southern abutment is exposed to small rock falls from the Otford Sandstone and small debris flows and boulder rolls uphill from the vegetated slope. Scaling of loose material supplemented by reinforced shotcrete to cover the weathered Otford Cliffs was provided. Also, the existing catch fence (0.01 MJ capacity) above the road was extended to the south to stop small rocks from reaching the road.

6.2 GD3 - GD4 transition - Casting Bed and Northern Abutment

The casting bed for the northern bridge was located below Scarborough Sandstone cliffs near the boundary between GD3 and GD4. The new road alignment at this location is approximately 2m higher than the old road alignment. As such, it was possible to create a catch ditch between the new alignment and the toe of the cliff, to significantly reduce the likelihood of rocks impacting on the new road.

Additional works included selective boulder removal from the slopes using hand removal and "slow burn explosives", together with scaling of loose rocks from the Scarborough Cliff above the site.

6.3 GD4 - Northern Amphitheatre

The main hazards occur from the southern half of the amphitheatre and include:

- Rock falls from the Bulgo cliffs, which may occur as individual boulders or large-scale cliff collapses of up to 1,000 m^3, and
- Debris flows from the Bulgo cliffs and/ or the Stanwell Park slopes, which may occur as individual flows or as multiple flows up to about 3,000m^3 in the one rainstorm event.

The hazards from the northern half of the amphitheatre are much less because of the limited size of the Bulgo cliff, and the relatively fine nature of the accumulated colluvium on the slopes.

Rock falls and debris flows in GD4 were modelled to assess likely run-out distances, flow velocities, run-up heights, and impact energies for use in the design of mitigation measures. Computer programs RocFall (Rocscience, 2002) and CRISP (Jones et al, 2000) were used to model individual rock fall events from the Bulgo cliff, and DAN/W (Hungr, 1995) was used to model major rock fall events and debris flows. The material parameter inputs into the analyses were modified as appropriate following the results of calibration modelling of selected rock fall and debris flow events on site.

The DAN/W analyses indicated a 3,000m^3 debris flow would cross the road at about 10 to 15m/second in a path 15m to 20m wide by 2m deep, pulsing to 3m deep. The impact energies of debris flows on structures, which are dominated by large boulders travelling on the debris flow front, were calculated to be about 8 MN for a 1m diameter boulder.

Remediation options proposed to address the hazards in GD4 included bridges, deflection berms, large containment basins, and hazard removal. The adopted works included a debris termination bund and catch ditch (Figure 6), earthworks upslope of the bund and drainage modification, together with raising the road alignment to lessen the potential for the various landslide hazards to impact on the road.

Figure 6: Debris termination bund and catch ditch in GD4
Photo courtesy of RTA

6.4 GD4 - Below the road

Below the road in GD4 there is a 10,000 m^3 landslide plus two smaller landslides. Sea erosion of the toe of the major landslide was anticipated to exacerbate the instability and the potential impact upon the road.

2000-2009

The Alliance considered constructing a seawall, with the intent of protecting the lower portion of the steep slope below the road from wave erosion. A preliminary design for the proposed seawall was proposed but considered to be too expensive. In 2015 an alternative seawall design was implemented (Young et al, 2015).

6.5 GD5 – Northern Headland

The Northern Headland (GD5) is not by-passed by the bridges. Significant hazard reduction was achieved by the pre-split and extensive scaling work done in November 1967. Further scaling and rock stabilisation mesh were applied, supplemented with spot bolts and claystone protection, together with a fence at road level to prevent small rocks reaching the road.

7 OUTCOMES

The design and construction took two years, with the opening ceremony officially held on 1 December 2005, nearly three months ahead of schedule. The success of the alliance model and the project team's approach on the bridge's construction helped lead the way for similar project delivery models to be used elsewhere, including being used on the Pacific Highway and Hume Highway upgrades.

To deliver major infrastructure of this magnitude in two years starting from a blank piece of paper is remarkable. The project received positive coverage in the local and national press and the community have embraced the Sea Cliff Bridge. The project is renowned and praised not only in engineering circles nationwide but also by the wider public and in international publications.

8 ACKNOWLEDGEMENTS

This paper refers to work undertaken for the Roads and Traffic Authority (RTA). The RTA was the New South Wales Government's agency responsible for road infrastructure, driver licensing and car registration between 1989 and 2011. It was superseded by Roads and Maritime Services between 2011 and 2019. From December 2019 Roads and Maritime Services and Transport for NSW merged to create an integrated transport agency known as Transport for NSW. Permission by the Transport for NSW to publish this paper is gratefully acknowledged. The views expressed in the paper are solely those of the authors.

The planning, investigation, design and construction for this project was carried out by a group of people with a wide range of skills and experience working effectively together. Every member of the Alliance should take credit for the successful outcomes including the completion of the spectacular Sea Cliff Bridge (Figure 7) ahead of schedule.

This paper describes some of the project's geotechnical issues. The following members of the Alliance contributed to the geotechnical work described in this paper: Alan Moon, Colin Parker, Garth Powell, Denis Byrne, Harry Poulos, Howard Rosser, Leon Lorenti, Michael Norman, Robert Wilson, Weiwei Li (Coffey Geosciences Pty Ltd), Mark Hendrickx, Ian Stewart, Greg Won and Val Brizga (NSW RTA), Phil Flentje (University of Wollongong).

For further information about the design and construction of the bridge see RTA (2006).

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PROFESSOR MARK JAKSA CHAIR 2004-05

For AGS members, being between a rock and a hard place is business as usual.

Since I joined the AGS in 1984, as a new civil engineering graduate, having just begun my first job with Coffey and Partners in Adelaide, the Society has been 'family' for me. I have loved – and still do – being a part of it, contributing to it, and in the latter part of my career, helping to shape it. There is no doubt in my mind that the AGS has had a significant and positive influence on my career and in my life. Being a university academic, I have the privilege of interacting with and helping to influence the lives of many young people. If they show some interest in geotechnical engineering, I always encourage them to consider joining the AGS, mainly for the reasons I've articulated above.

After having had the privilege of Chairing the 7th Australia New Zealand Conference on Geomechanics in Adelaide in 1996, I was asked in 1999 to join the National Committee of the AGS. I was later approached to be the Deputy Chair, and I served as Chair in 2004 and 2005. My 17 years serving the National Committee, in total, have been extremely enjoyable, as was my two years as Chair. Without doubt, the most important matter that the AGS dealt with during these two years was its health, which was intimately linked with the Secretariat.

During my time on the National Committee, secretarial services were provided to the AGS, for a fee, by Engineers Australia. We were privileged to have the services of a lovely, kind, gentle and competent lady, Ms Valerie Lee. Just like Peter Robinson does now, for nine years Val managed the day-to-day affairs of the society, memberships and, of course, the finances. Whilst Val was competent in all of the skills needed to service the AGS, the Executive – Andrew Leventhal, Marc Woodward and myself – knew that, with the continually growing membership and the increasing and demanding needs of the society, we needed to raise and improve the level of secretarial support. Val was an employee of Engineers Australia and, as such, she was managed by, and received her authority from, EA. At the time, Val provided secretarial services for the AGS, as well as two other technical societies of Engineers Australia.

We met with the leadership of EA in order to seek a greater proportion of Val's time, but we failed in this endeavour. Action was required, as the status quo wasn't working, and our finances were declining. Furthermore, Val was planning to retire in 2006

Andrew suggested that we approach a former colleague of his, Peter Robinson, which I did, and the rest is 'history', as they say. Since that time, the AGS's finances, membership and activities have grown considerably, much of which is a credit to Peter's skills and stewardship of the AGS's finances. I am very proud to have been part of that decision. Sadly, Val succumbed to the breast cancer that she had lived with for many years and she passed away in 2011.

During 2004 and 2005, the Landslide Risk Management initiative continued to progress under the leadership of Immediate Past Chair Andrew Leventhal, and Professors Neil Taylor, David Potts, Scott Sloan and John Carter gave lecture tours around Australia. In February 2004, more than 230 delegates attended the very successful 9th Australia New Zealand Conference on Geomechanics in Auckland.

The inaugural AGS Practitioner of the Year was won by Prof. Harry Poulos. The total number of AGS members also continued to grow during this period and rose from 977 in April 2004 to 1,051 in November 2005.

In July 2004, the 6th ANZ Young Geotechnical Professionals Conference was held in the Gold Coast and, again, was well attended and well received.

Mark thanking Valerie Lee for her services to the AGS and wishing her all the best in her retirement (Nov 2005)

Australian Geomechanics Society

Internet Web Site

www.australiangeomechanics.org

M. B. Jaksa (Webmaster, email: mark.jaksa@adelaide.edu.au)

The Australian Geomechanics Society actively maintains an internet web site that can be found at www.australiangeomechanics.org. The web site contains the information about the Society, its constitution, the National Committee, supporting members, membership details and forms, prizes and awards, upcoming conferences, useful geotechnical links and information related to *Australian Geomechanics*, such as advertising rates, recent tables of contents and author instructions. Most importantly, the web site contains links to the web pages of the various AGS Chapters. In this way, members can easily see what is going on in their chapter, as well as others around Australia. It is a good idea, before attending a meeting in your Chapter, to check the relevant web site for the latest information. Any suggestions for improving or updating the web pages, will be warmly received.

CHAIRMAN'S COLUMN

Welcome to the second edition of *Australian Geomechanics* for 2005. I trust that this edition finds you well and in good spirits. I'd like to begin by thanking Fiona MacGregor, Patrick's daughter, for organising this edition while Patrick is overseas. Fiona, your hard work is greatly appreciated.

AGS Awards

Since the last edition, two AGS awards have been decided. The first is the 2005 E. H. Davis Memorial Lecture, which was awarded to Prof. John Carter, Challis Professor in Civil Engineering, at the University of Sydney. Members will recall that John was a recent former National Chair of the AGS and is the newly elected Vice-President for Australasia of the ISSMGE. Congratulations John on this well-deserved recognition. John's lecture will be presented early next year and will appear in *Australian Geomechanics* shortly thereafter.

The second award is the inaugural *Australian Geomechanics* Award for the best paper published in *Australian Geomechanics* in 2003. This was presented to Ray Gordon from the WA Chapter for his paper entitled "Coastal Limestones" that was published in the December 2003 issue. Again, congratulations to Ray.

ISSMGE News

Recently, the ISSMGE announced that Prof. Harry Poulos was named as the recipient of the 2005 Kevin Nash Gold Medal. This award is presented every 4 years at the International Conference on Soil Mechanics and Geotechnical Engineering – this year in Osaka, Japan – to a geotechnical engineer who has made a major contribution to fostering the ideas and goals of the ISSMGE. The medal remembers Prof. Kevin Nash, the ISSMGE's Secretary General between 1965 and 1981. Heartiest congratulations to Harry on another well-deserved award to add to his overflowing trophy cabinet.

The latest ISSMGE (March 2005) newsletter is available for download from the AGS web site (www.australiangeomechanics.org/page52.htm).

Geology for Engineers Course

The biennial *Geology for Engineers* course, presented by Alan Moon and Fred Baynes, will be held at the University of Adelaide between Tuesday, 28 March and Friday, 7 April 2006. This is the third time the AGS-endorsed course has been run, and past attendees have expressed high praise for the course and its presenters, who are highly respected engineering geologists. The course features practical material and significant hands-on content. Registration is limited to only 18 students and places will fill fast. A brochure is included in this issue's mail out. If you have misplaced yours, or have any questions regarding the course, please do not hesitate to contact Alan Moon (alan_moon@coffey.com.au).

Vignette from Australian Geomechanics Vol 40 No 2 June 2005

2000-2009

MARC WOODWARD CHAIR 2006-07

The world and geotechnical engineering have changed dramatically since I first worked on a civil engineering site in 1977. Thankfully I think AGS has successfully moved with the times and manages to represent the combined essential fundamentals of professional engineering skills, sound geological knowledge, construction practicalities and good management practices.

My two most memorable AGS related events for the 2004–07 period during which I was Treasurer and then National Chair, are putting the AGS secretariat and financial control under Peter Robinson, and the successful nomination of Fred Baynes as the International President of the International Associated on Engineering Geologists (IAEG).

With the appointment of Peter Robinson by AGS the society took direct control of its own destiny and was immediately much more independent and transparent in terms of membership, budgets and finances. I understand that, in the years after this decision was implemented, AGS membership numbers, management reporting and financial circumstances, have all flourished.

AGS nomination and support of Fred Baynes as President of IAEG developed closer ties between AGS and IAEG and also with the international community and other international professional bodies.

Other key events that I recall helping the practice of geotechnical engineering in Australia, New Zealand and overseas include the very successful October 2007 10th ANZ Conference "Common Ground". Burt Look and the ANZ committee did a great job organising the conference which was very successful technically, professionally and socially.

The AG publication of collected Landslide Risk Management (LRM) papers in March 2007 presented the significant achievement of Andrew Leventhal and his team in producing this very valuable body of work. It was pleasing to note recognition of this work with Civil College of Engineers Australia awarding the 2007 Warren Medal to Robin Fell, Bruce Walker and Tony Phillips for their suite of LRM papers.

In my time as chair I was delighted to work with Patrick McGregor and support his fantastic efforts with editing AG. In particular, I was pleased that we put some effort into making communication with the AGS committee more accessible with the 2006 "Rogues Gallery" and supported Mark Jaksa in development of the web page.

The period 2002–2007 was at the height of the WA Iron Ore boom and, although my AGS role was national, my project work at the time was generally WA focussed.

The race between Rio Tinto in Dampier, BHP in Finucane Island, Port Hedland and newly arrived FMG, to rapidly increase iron ore mining and export facilities, alongside concurrent major Oil and Gas projects in the north of WA for Woodside and Chevron, created a "perfect storm" in the geotechnical profession. Huge numbers of new engineers and geologists poured into WA to deliver ground investigations, geotechnical design solutions and construction delivery for major projects in the Pilbara and the north of WA. Railways in remote WA, complete new mine sites and coastal stock yards, car dumpers and load out jetties were constructed in record time as the major export clients battled to meet delivery commitments. My personal biggest professional challenge at the time was to recruit and manage lots of newly arrived engineers and geologists who had come for the employment boom but often had little or no previous WA experience.

My work in WA has involved temporary ground retention for many major and routine excavations. Some of the more interesting and challenging projects have included major excavations in close proximity to the coast to enable construction of deep car-dumper infrastructure. CD4 in Port Hedland was one such project and, as indicated in the attached photographs, required significant anchored sheet pile walls to support the variable ground conditions to an excavation depth well below the ground water.

One particularly interesting project was anchoring the Busselton Jetty Underwater Observation chamber to the sea floor. High capacity anchors were required to resist buoyancy uplift once the chamber was emptied of water. These anchors had to be drilled, installed and grouted below water immediately adjacent to the jetty piles and coral. Innovative cased drilling systems and underwater grouting operations were developed to ensure adequate anchor capacity whilst preventing contamination of the surrounding marine environment.

Construction of car-dumper infrastructure CD4 in Port Hedland with significant anchored sheet pile walls

One of the main non-WA projects I had some involvement with was the Gateway Bridge duplication in Brisbane. The construction of the new bridge across the Brisbane river threw up some interesting geotechnical challenges in terms of investigation and design as well as construction methodologies. In particular, optimising the design philosophy and settlement considerations for very high capacity drilled piles founded in high strength bedrock presented some interesting topics for consideration and review.

My earlier, similar work, on the piling for the Narrows Bridge duplication in Perth, and other WA based marine piling works, was valuable in helping optimise the analysis and design approach adopted in Brisbane.

Looking back at my AGS years I think the most positive thing I take from the role was the opportunity to widen my Australian geotechnical horizons beyond WA with new contacts and connections across Australia, New Zealand and outside Australasia.

90 KM THROUGH THE WEST AUSTRALIAN DESERT

GEOFF COCKS

RUSSELL CLAYTON

Geoff Cocks studied at University of Western Australia and Purdue University, Indiana. He was employed by Main Roads Western Australia for 20 years and Coffey for 25 years.

Russell is a Technical Director of geotechnical and pavement engineering at GHD and has been consulting on major roads and airfield pavement engineering projects for thirty years as designer and team leader on major projects. He has consulted on projects in Australia , Canada, USA, Southern Africa, Middle East, Philippines and numerous islands in the Indian and Pacific ocean regions.

INTRODUCTION

Karratha Tom Price Road (Stage 2) was designed, constructed and maintained for 8 years under an Alliance Contract. The Alliance participants were Main Roads Western Australia, Macmahon Contractors, GHD and Coffey.

Stage 2 was located in the Pilbara region of North West Australia. Approximately half of the 90 kilometre length was located in a National Park where there were strict controls on clearing.

At the time of award of the Alliance contract, the alignment of the proposed road was not fixed. The Alliance form of contract offered an opportunity to challenge some of the traditional ways of doing things. This paper describes some of the traditional and non-traditional ways of doing things. In line with the philosophy of doing things a bit differently, the paper describes things that didn't go so well together with some of the things that went well.

Figure 1: Karratha Tom Price Road (Photograph by 21CC)

KARRATHA TOM PRICE ROAD

Stage 2 of the Karratha Tom Price Road (KTP2) was a 90km long section of a much longer road project that will ultimately link the mining town of Tom Price with the City of Karratha which is located close to the port of Dampier from which iron ore is exported.

The ore is transported by rail. KTP2 replaces a privately owned rail access road for which tourists required a permit to travel and which was unsuitable for conventional two wheel drive vehicles or for other than off-road caravans. KTP2 was constructed as a sealed road. At the time of design the expected traffic was about 125 vehicles per day, most of which would be light vehicles and small trucks. Iron ore is not hauled on the road. The road provides improved access for remote communities, better access to a National Park for tourists and a safer road for the rail maintenance teams that look after the iron ore rail line. About half the length of Stage 2 is located in a National Park. There were strict environmental controls for the section in the Park including a maximum permitted total clearing area and strict limits (effectively a ban) on borrow pits within the Park. The deepest cuts and highest fills are located in the Park section of the route. The project included more than 100 cuttings most of which were in rock. The Pilbara Region in which the project is located has a hot arid climate. Key features of an Alliance form of contract are equitable sharing of risk between the owner and non-owner participants and the embedding of the owner's staff in the design and construction teams. In terms of risk sharing, the "team", including some of the owner's staff, prepare a target cost which is subject to independent audit. Cost savings or cost overrun are shared equally between the owner and non-owner participants. Non-owners are guaranteed their direct costs but their profit and corporate overheads are at risk. Not all things went as well as hoped on the project and some worked better than anticipated. This paper gives a brief overview of what worked well and what not so well in the geotechnics space.

SITE INVESTIGATION

For "construct only" and "design and construct" contracts it is common for lots of boreholes to be drilled prior to calling for bids. The logs of these boreholes are used by designers for such purposes as cut slope design and by tenderers to estimate excavation costs. However such drilling is expensive both in dollar terms and in time. On a project such as KTP2 a traditional "drill first, think later" approach would probably have taken about a year. There was the added complication on this project that at the time of contract award the alignment had not been fixed. There was a corridor about 1km wide in which the road could be constructed. Drilling would have required clearing of access tracks and drilling pads; a problem with the strict limit on cleared area in the National Park. While the project included more than 100 cuttings, some about 20m deep in rock, not a single geotechnical borehole was drilled. The approach adopted was to carefully examine the rock cuttings on the rail formation that the road follows. Surface exposure adjacent to cuttings was noted. The entire 90km of the preliminary road route was then walked by a team of Engineering Geologists and Geotechnical Engineers to assess likely subsurface conditions. A measure of the success of this approach is the proportion of material in cuttings requiring blasting. When the alignment had been fixed, a D10 dozer was used to document the rippability of the various geological units. Based on geological mapping and site observations it was estimated that 69% of material in cuttings would require blasting. The actual proportion of drill and blast when the project was completed was 72%, nearly 1 million m^3 of hard rock. Bearing in mind the time saving by not drilling for investigation, this approach was a success.

AN INTEGRATED GEOTECHNICAL TEAM

The geotechnical team for the project included geotechnical engineers, engineering geologists and materials technicians drawn from Coffey, GHD and Main Roads WA, working as one unit. There was also an external blasting expert in the team. Team members included those whose prior experience was predominantly in Western Australia, South Africa, Victoria and South Australia. This brought a broader range of skills than might have come from any single organisation and fostered methods not previously adopted in Western Australian Road design and construction, balanced with local experience. The overall integrated geotechnical team was located in the project design office enabling seamless discussions between Geometric and drainage designer as well as the Contractor. Some cooperative relationships developed on KTP2 have lasted well past completion of KTP2. It certainly helped avoid a "blame game" when later some things didn't go as well as planned. Overall the integrated team approach worked well.

BLAST DESIGN TO GET AT LEAST 0.5 METRES OF BROKEN ROCK BELOW SUBGRADE LEVEL

An all too frequent problem with rock cuttings in the Pilbara and Kimberley Regions of Western Australia is pavement failures caused by water trapped in the pavements through rock cuttings. The water isn't there all the time but appears following periods of intense long duration rainfall events. With a rectangular or triangular blast hole pattern the base of a cutting after blasting can be imagined as being a bit like an egg carton with peaks and valleys which can trap water. On KTP2 blast hole depths were designed such that there would be at least 500mm of broken rock above the peaks of unbroken rock. This broken rock could then act as a drainage layer allowing water to escape to the deep table drains. 500mm was more than twice the 200mm normally specified in Main Roads WA projects. With more than 100 cuttings, only one has experienced pavement failure due to water in the subgrade. The adoption of a minimum 500m broken rock thickness below subgrade level in rock cuttings worked well.

APPLICATION OF QUANTITATIVE RISK ASSESSMENT TO ROCK SLOPE DESIGN

The Quantitataive Risk Assessment (QRA) method proposed by the Australian Geomechanics Society for landslide risk was adapted and applied to design of slopes in rock cuttings where falling rocks reaching the road pavement are a potential hazard. Pilbara Rail provided copies of their photographic records of rock cuttings in the rail formation to be followed by KTP2. By comparing the photographs with field observations an estimate of the frequency and size of fallen rocks was made. This was then applied to the proposed new road cuttings in the same geological units. The QRA method provided a balance between the extremely high cost of having very flat cut slopes and very wide rock catch ditches with the hazard to traffic of fallen rocks in the traffic lane. There was a saving in rock excavation volume. Cuttings were inspected annually by a member of the Geotechnical Team in the 8 years after the road was open. No evidence of a fallen rock causing a crash was identified (no vehicle crash debris). The QRA approach is counted as a success.

APPLICATION OF QUANTITATIVE RISK ASSESSMENT TO FLOODWAY DESIGN

The project included design of a floodway across Western Creek where flows over the road pavement following a major rainfall event could be several metres deep. The design was highly constrained with a rail line running parallel to the creek (a fixed elevation constraint for the road pavement), two connecting road junctions, a specified design speed of 110km/hour, and performance criterion that limited the time the road could be closed due to flooding. This forced a floodway design with the road pavement on an embankment 5 metres high across the creek. There are several hazards with a floodway on a high embankment. Vehicles attempting to cross the floodway when water is flowing may be washed off (yes people do drive into floodways when the water is flowing strongly!). When the floodway is dry, vehicles may run off the road on the upstream or downstream sides, crashing into the large rocks used as erosion protection (guard rails are not an option for a floodway). Vehicles may crash into trees or other debris left on the pavement after a major flood. The geotechnical team proposed to the civil design team that the QRA approach adopted for the rock slope design could be adapted to help with design of this major floodway. The risk associated with vehicles running off a 5m high embankment or of colliding with debris adjacent the road was evaluated using the Roadside Impact Severity Calculator (RISC) program, and reasonable estimates were made of the risk of vehicles being washed off the road during a flood. Several different floodway designs were assessed for risk. The resulting design reduced the design speed to 80km/hour and resulted in an embankment less about 2 metre high (rather than 5m) for most of the floodway length. Applying QRA gave a safer floodway that cost about $1 million less to construct.

DESIGN AND CONSTRUCTION OF PAVEMENT OVER EXPANSIVE CLAY

KTP2 wasn't all rock cuttings and rock fills. About 20km of the length was founded on expansive clay referred to as Gilgai on geological maps of the area. For samples compacted to 92% of modified maximum dry density the average soaked California Bearing Ratio (CBR) was about 2% and the average swell in the CBR test was about 11%. The Gilgai clay was about 1.5m thick and underlain by rock. The Gilgai, when dry in its natural state had deep cracks up to about 100mm wide at the surface. The approach adopted to deal with the Gilgai aimed at maintaining the clay at an equilibrium moisture content with little change during the operational life of the pavement and included the following steps:

- Special attention to drainage design and construction to minimise the occurrence of water ponding near the road pavement for any significant length of time;
- Wide flat fill batters such that the toe of the embankment was a long way from the pavement;
- Lightly ripping the Gilgai to break up the existing crack pattern;
- Applying as much water as possible (limited by the need for construction equipment to move over the surface) to the Gilgai to hydrate the clay to an anticipated equilibrium moisture content in the future;
- Only lightly compacting the clay with the Specification including an upper limit on compaction as well as a lower limit;
- Covering the Gilgai while it was still moist with about 600mm thickness of non-reactive fill;
- Allowing the Gilgai to cure under the non-reactive fill for a period of 4 months prior to placing and compacting the pavement layer (150mm base course). Soil suction and surface movement were monitored during this period; and
- Part width sealing of road shoulders, despite the expected low traffic volume.

For 7 years after completion of the pavement, surface movement on a selected section was monitored by surveyors measuring the elevation of nails in the sealed portion of the road shoulder. Average movement was 25mm and the road shape acceptable with no cracking attributed to the expansive clay. If we assume that Shrink Swell Index Iss is about 0.6 times CBR swell (for samples compacted at modified optimum moisture content), then much more movement than this would be expected.

Figure 2: Western Creek Floodway and adjacent Rail Level Crossing (Photograph by 21CC)

The various steps taken must have significantly reduced the changes in soil suction change in the clay to less than the 1.2pF commonly adopted for surface movement calculations. The approach adopted for construction over expansive clay worked well and has since been adopted on other projects.

BITUMINOUS SURFACING

Most of the northern half of the project was constructed over a marginal base course material consisting of ripped and crushed Greenstone that was modified with cement. Two bituminous surfacing treatments were adopted. In floodways the bituminous surfacing consisted of a prime (cutback bitumen) followed a few days later with a double double seal (14mm and 7mm aggregate) using hot bitumen. Between the floodways, a primer seal using cutback bitumen with crusher dust from a quarry as cover was applied and used by traffic for about a year. A 14mm hot bitumen seal was then applied. The prime and double double seal worked very well. The primer seal with a seal a year later did not work so well, with some potholes and some flushing.

Further south on a long (2km) steep (6%) grade a prime with a seal using polymer modified binder seal was used. This worked better than adjacent, less stressed sections where a primer seal and class 170 bitumen seal were used.

The Western Creek floodway was surfaced with asphalt and performed well, surviving a major flood event with only minor damage. The asphalt standard mix design was modified with a small increase in binder content for floodway conditions.

USE OF MARGINAL MATERIAL AS BASE COURSE

Main Roads Western Australia has successfully used marginal quality natural gravels as basecourse on roads carrying low to medium traffic volumes for several decades (see Cocks et al 2015). The geology along the route of KTP2 did not lend itself to the formation of materials normally used for pavement construction in the Pilbara Region. So the envelope was pushed a bit further. Most of the base course in the northern half of the project was constructed using a Greenstone that was ripped, crushed in an impact crusher and modified with either 1.25% or 1.5% cement. The unmodified material sampled from backhoe test pits looked good with a soaked CBR of about 100%. However by the time the material had been processed through an impact crusher to deal with oversize and compacted on the road, the soaked CBR had dropped to about 40%. While it had originally been planned to cement-modify the base course in just the floodways, a decision was taken to cement-modify all of the base course material derived from Greenstone.

For the southern half of the project, the base course was a marginal quality natural lateritic gravel. The typical soaked CBR was 75% and the plasticity index 17%. The percentage passing 0.425mm sieve was 15%. Materials with similar properties had previously been used successfully on low traffic volume roads in the arid Pilbara Region. The base course in floodways was cement-modified.

Shortly after construction was completed the area was subject to an extreme rainfall event. Water flowed over the road more than 5 metres deep in one location and there was significant erosion damage. The adjacent railway embankment that had been in place more than 40 years was washed away in several places. Triple road trains were used to haul large volumes of soil and rock for rail embankment repairs. Put in plain terms the KTP2 pavement copped a pounding when it was in a wet condition. The unmodified pavement constructed with marginal gravel did not perform as well as had been expected. Shallow ruts continued to develop in the pavement constructed using marginal quality natural gravel in the years following the major rainfall event, and ultimately about 15% of the area was repaired using cement modification. With the benefit of hindsight, it would have been better to cement-modify the entire length during initial construction.

CONCLUDING COMMENTS

From a geotechnical perspective, more things went well than not so well. Under an Alliance Contract framework, the project was delivered earlier than it could have been under other contract models with the contract awarded before the road alignment had been fixed. The financial outcome was a mixed story. The direct cost was significantly above the original estimate. The client paid more and the non-owner participants forfeited a portion of their corporate overhead and profit margin. On a positive note, under an Alliance Contract model the cost increase was dealt with without the need to resort to expensive litigation.

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Photographs by 21CC

NEIL BENSON CHAIR 2008-09

> The AGS provided leadership in how to run a successful technical society within the structures of Engineers Australia

The 2008-2009 period of my tenure as Chair was characterised by change; both globally, locally and within the AGS. Externally in 2008 the global financial crisis was in full flow but after the changes introduced by my predecessors, Mark Jaksa and Marc Woodward to both the AGS Secretariat (Peter Robinson), financial controls and independent control over administration, the AGS was well positioned. Indeed, by the end of 2008 the AGS became EA's largest technical society. Membership grew to, I recall, to circa 1300 members by the end of 2009 and during 2009 we were able to sponsor a series of strategic initiatives for members. These included:

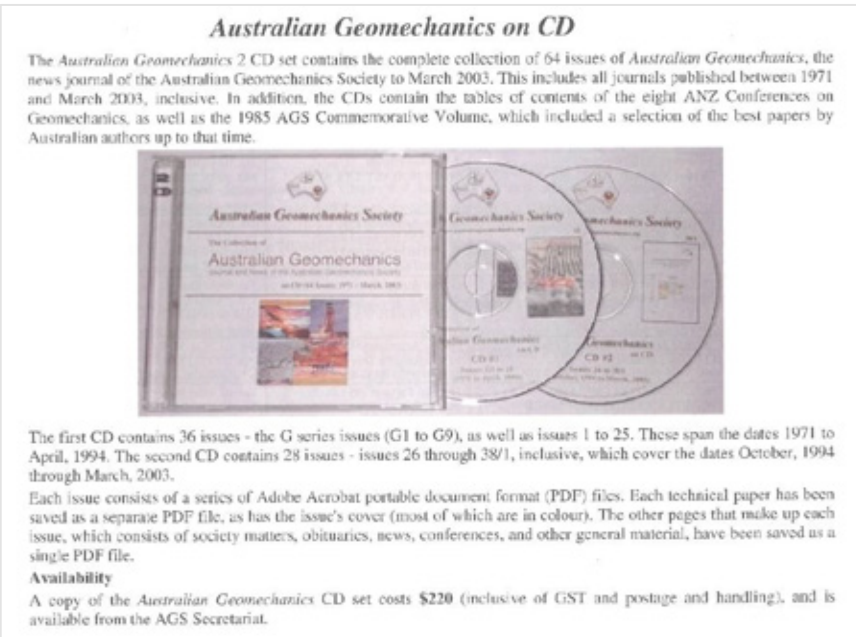
- Sponsoring the development of a new Engineering Geology CPD course
- Development and launch of a new website (stage 1) in March 2009
- Re-initiation of the Distinguished Speakers program
- Introducing free membership for full time students
- Publishing a referenced CD of all AGS papers from 1971-2009 to all recipients of the AGS Journal.

The AGS Landslide sub-committee or Taskforce, active under the leadership of Andrew Leventhal, was successful with a submission to the National Disaster Mitigation Programme for funding to run workshops Australia wide on Landslide risk management. In addition, I was fortunate to join Andrew at Parliament House, Canberra in late 2008 as the representatives of AGS and the Sydney Coastal Councils Group to receive an Australian Safer Communities Award for projects of national significance from the Attorney General. I recall the "Letters to the Editor" was a busy section of the AGS Journal during 2008 as practitioners debated the "Practice note guidelines for Landslide Risk Management" first published in December 2007.

Patrick MacGregor was our dynamic Editor of the AGS Journal, and he had introduced Sara Lanesman in a part time role to coordinate advertising which we promoted to underpin the costs of issuing the Journal to all members.

On the International Society front John Carter was VP for ISSMGE, Alan Moon for IAEG and Tony Meyers for ISRM. Fred Baynes was the International President of IAEG. FIGS or FedIGS, the Federation of International Geo-Engineering Societies was initiated in 2007/2008 as an umbrella organisation linking the major international professional societies.

Another memorable occasion was the presentation (retrospective) of a memento for the EH Davis Lecture concurrently to the 2003, 2005 and 2007 nominees in Newcastle. (John Carter, Scott Sloan, Chris Haberfield). I believe this became a formal award in future years.



Australian Geomechanics on CD

The *Australian Geomechanics* 2 CD set contains the complete collection of 64 issues of *Australian Geomechanics*, the news journal of the Australian Geomechanics Society to March 2003. This includes all journals published between 1971 and March 2003, inclusive. In addition, the CDs contain the tables of contents of the eight ANZ Conferences on Geomechanics, as well as the 1985 AGS Commemorative Volume, which included a selection of the best papers by Australian authors up to that time.

The first CD contains 36 issues - the G series issues (G1 to G9), as well as issues 1 to 25. These span the dates 1971 to April, 1994. The second CD contains 28 issues - issues 26 through 38/1, inclusive, which cover the dates October, 1994 through March, 2003.

Each issue consists of a series of Adobe Acrobat portable document format (PDF) files. Each technical paper has been saved as a separate PDF file, as has the issue's cover (most of which are in colour). The other pages that make up each issue, which consists of society matters, obituaries, news, conferences, and other general material, have been saved as a single PDF file.

Availability

A copy of the *Australian Geomechanics* CD set costs **$220** (inclusive of GST and postage and handling), and is available from the AGS Secretariat.

2000-2009

VIEW FROM THE CHAIR

Welcome to the final edition of Australian Geomechanics for 2009. This issue, my last as AGS National Chair, finds the industry with greater levels of hope and positive anticipation for the future than when my term as chair started in 2008. The last two years have also seen considerable change for the Society: the launch of the new website, improvements to our financial condition (building on the efforts of previous chairs, Mark Jaksa and Marc Woodward) and the growth of the Society to be one of the largest Technical Societies within Engineer's Australia (AGS membership currently stands at 1281). Enclosed within this edition you should find a reference DVD which contains copies of all papers published in Australia Geomechanics from 1971 to end of 2009 (this edition). Our thanks to Patrick Macgregor and Peter Robinson for their work in organizing this for the benefit of our members.

The 8th Annual General Meeting (AGM) of the Australian Geomechanics Society was held in Sydney (Coogee) on 2nd October 2009, followed by the National Committee meeting. At the AGM Graham Scholey was elected as AGS National Chair for 2010 and Sam MacKenzie as Vice Chair/Treasurer. We welcome Sam to the Executive of the Society. My congratulations to them both on their appointments. Service awards were presented to retiring members of the National Committee: Paul Hewitt (Sydney), Chris Boyd (Victoria) and Brenton Harris (South Australia).

At the National Committee meeting we agreed to devolve leadership responsibility for certain National Committee activities to the following state representatives:

Distinguished Speaker Program – NSW (Sydney)

Awards – Victoria

Standards Australia Reports - Newcastle

EVENTS

The **IAEG Congress** (which is held every four years) is the biggest international event in the IAEG calendar. Registration for the **Auckland IAEG Congress** is now open and a "discounted super early bird" registration fee is available until 31 March 2010 (see the congress website: www.IAEG2010). As Fred Baynes points out in the registration brochure the congress is the premier international event for engineering geologists and other interested professionals to interact, talk, learn about their science and have fun. The AGS will provide **$1000 support for a young engineering geologist to attend the congress.**

The **AGS Engineering Geology** Course being developed by Alan Moon, Fred Baynes, Mark Eggers and Phil Flentje is now scheduled to run for the first time from Saturday 25th September to Sunday 3rd October 2010 and is based in Wollongong. This edition of the Journal includes a revised Technical Note that provides an overview of the Course. A

Vignette from *Australian Geomechanics* December 2009

INVESTIGATING THE LANE COVE TUNNEL COLLAPSE

Ted Brown is a civil engineering graduate of the Universities of Melbourne, Queensland and London. His major appointments were as Professor of Rock Mechanics at Imperial College, London, as Deputy Vice-Chancellor and Senior Deputy Vice-Chancellor of the University of Queensland, and as Senior Consultant with Golder Associates. He served as Chairman of the British Geomechanics Society (1982, 1983), and as President of the International Society for Rock Mechanics (1983-87). He was made a Fellow of the Royal Academy of Engineering, UK, in 1989, a Fellow of the Australian Academy of Technological Sciences and Engineering in 1990, a Companion in the Order of Australia (AC) in 2001, and received the AGS's John Jaeger Award in 2004 and the ISRM's Muller Award in 2007.

PROFESSOR TED BROWN AC

BACKGROUND

My partner, Dale, habitually sleeps with an ear plug in her ear listening to the continuous news service on ABC News Radio. At around 4:00 am on the morning of Wednesday, 2 November 2005, Dale woke me to give me news of a significant leak in a water main and associated surface subsidence, near the site of a major tunnelling project at Lane Cove, Sydney. My immediate reaction was that the leaking water was unlikely to be the cause of the subsidence as the radio commentators were supposing, but that the water pipe had broken as a result of subsidence associated with the tunnelling.

During that day, images of the collapse and of its effects on an adjacent block of flats, in particular, were published in the press and on television (Figure 1).

When I arrived home from work that afternoon, Dale told me that Martin Albrecht AC, the then Chairman and former Managing Director of Thiess Pty Ltd, who I knew both professionally and socially, had telephoned looking for me. I tried to ring Martin at his office at Thiess but he wasn't there at the time. His PA knew that he was most anxious to speak to me and suggested that I ring his home telephone number. When I rang, Martin hadn't yet arrived home, but his wife kindly took a message. Martin and I eventually made telephone contact in the early evening that day.

Martin explained that Thiess was in a Joint Venture (JV) with John Holland for the design and construction of the Lane Cove Tunnel Project (LCTP), and asked if I would be available to carry out an immediate independent inquiry into the collapse that had occurred in the tunnelling works early that morning. I agreed, and Martin put me in contact with Thiess's then Chief Executive Australian Operations, David Saxelby, who had overall management responsibility for the LCTP.

Figure 1: Building damage resulting from the collapse at the intersection of the Marden Street ventilation tunnel and the Pacific Highway Exit Ramp, Lane Cove Tunnel Project, Sydney, 2 November 2005

2000-2009

Working through Rob Morphet in the Brisbane office of Golder Associates through whom I did my consulting work, David quickly arranged for my formal appointment to carry out an independent inquiry into the collapse.

That appointment was announced through a Press Release released at 7:00 am on Friday, 4 November.

I had agreed with David to be in Sydney to commence my work early on Monday, 7 November, although I did do whatever background reading as I could on the Project and its tunnels beforehand. From this distance, I can now admit that, as previously planned, I went to the first day of the Australia – West Indies Test Match at the Gabba on Thursday, 3 November, where I was privileged to see Ricky Ponting make a wonderful 149 following the early fall of Mike Hussey's wicket.

The Lane Cove Tunnel collapse was a, perhaps the, major item on most Australian news outlets over several days from 2 November 2005. This caused me to have an interesting experience on the morning of Friday, 4 November, when I went to the Port of Brisbane where I was then a Board member. We had a scheduled meeting of the Board's Planning and Environment Committee at the Port that morning, but before that there was an opening ceremony for a new wet land bird roost that the Port had developed for migratory birds.

When I arrived at the appointed place for the opening just before 8:30 am, the Board Chairman, David Harrison, was being interviewed by Virginia Trioli who was then the breakfast presenter on one of the ABC radio stations.

She had just seen the Press Release concerning my appointment to inquire into the Lane Cove Tunnel collapse, and noting that I was a member of the Board of the Port of Brisbane Corporation, said to David that she assumed that he knew me. David replied that indeed he did, and that he could see me just then walking across the road nearby. Virginia was quick off the mark in asking if she could speak to me. I've been eternally grateful to David ever since for demurring, no doubt because he correctly wished to maintain the focus of the interview on the Port's new bird roost. At that point, I knew nothing definitive about what had happened at Lane Cove, had not been to the site, and was in no position to stand up to a cross-examination by Virginia Trioli whose reputation as an incisive interviewer preceded her.

THE INVESTIGATION

The Lane Cove Tunnel Project involved the construction of twin, 3.6 km long, two- and three-lane tunnels together with 3.5 km of bridge and road upgrades to link the M2 motorway at North Ryde with the Gore Hill Freeway, as well as a number of other elements. The twin east-bound and west-bound tunnels run beneath and slightly to the north of Epping Road. Figure 2 shows a schematic diagram of the tunnels in the LCTP, including the location of the collapse to surface at the junction of the Marden Street ventilation tunnel on design control line MC5B and the Pacific Highway Exit Ramp on design control line MCAA.

As planned, I travelled to Sydney early on Monday, 7 November 2005. Except for a quick trip back to Brisbane on 9 November to attend to a prior commitment, I

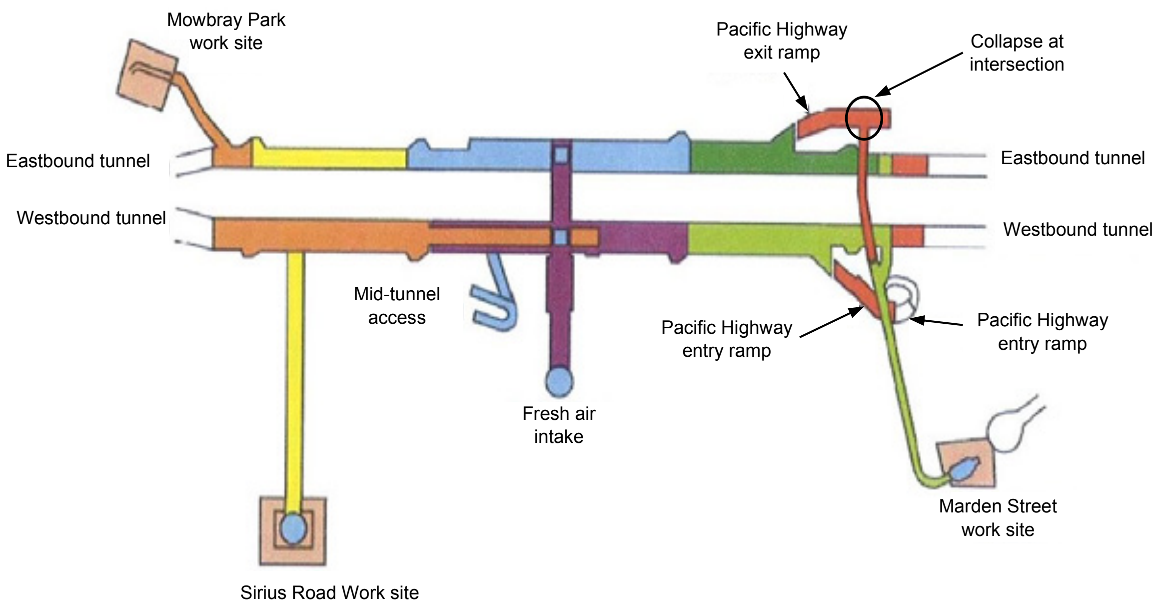


Figure 2: Tunnel schematic, Lane Cove Tunnel Project (Rozek 2005)

remained in Sydney until 11 November carrying out the following main activities:

- discussions and interviews with representatives of the contractor, the designer, the geotechnical consultant, and the crew and supervisors working at the collapse site at the time of the incident;
- a surface site visit;
- an underground visit to the site of the collapse and to inspect other tunnels in the Marden Street section of the Project;
- study of a wide range of design documents, drawings, construction reports and other documents; and
- giving preliminary consideration to the possible causes of the incident and the preparation of an outline of my report.

Following an introduction by David Saxelby, my most detailed interactions on site were with Steve Wille, the LCTP Construction Manager – Tunnels and Dr Philip Pells and Robert Bertuzzi, Principals of Pells Sullivan Meynink, the Project's geotechnical engineers. Following my return to Brisbane, on request, I was provided with a range of further materials which informed my consideration of the likely causes of the collapse. I set out a list of those likely causes in my Final Report (Golder Associates, 2005) submitted to the Hon Andrew Rogers QC on 9 December 2005. Importantly, I concluded that "*the collapse arose from a combination of factors that were not present together at any other location in the underground works on the Project*". It is to the credit of those concerned that my Report was soon released publicly.

In my Report, I paid particular tribute to the rapid response of Steve Wille and Rob Bertuzzi in the small hours of 2 November 2005 in deciding to immediately fill the subsidence hole with concrete, mainly to stabilise the Longueville Road bored pile retaining wall which had been under-mined during the initial collapse with several of the associated ground anchors being destroyed. This occurrence had potentially disastrous consequences for the stability of the wall and the road. As I said in my Report, "*the rapid response to this emerging issue, the engineering decision-making and the immediate implementation of remedial measures by the Construction Manager – Tunnels, the PSM partner and members of the design team, displayed levels of engineering skill and professional responsibility of the highest order*". Figure 3 shows a vertical section through the site following the concrete pours.

2000-2009

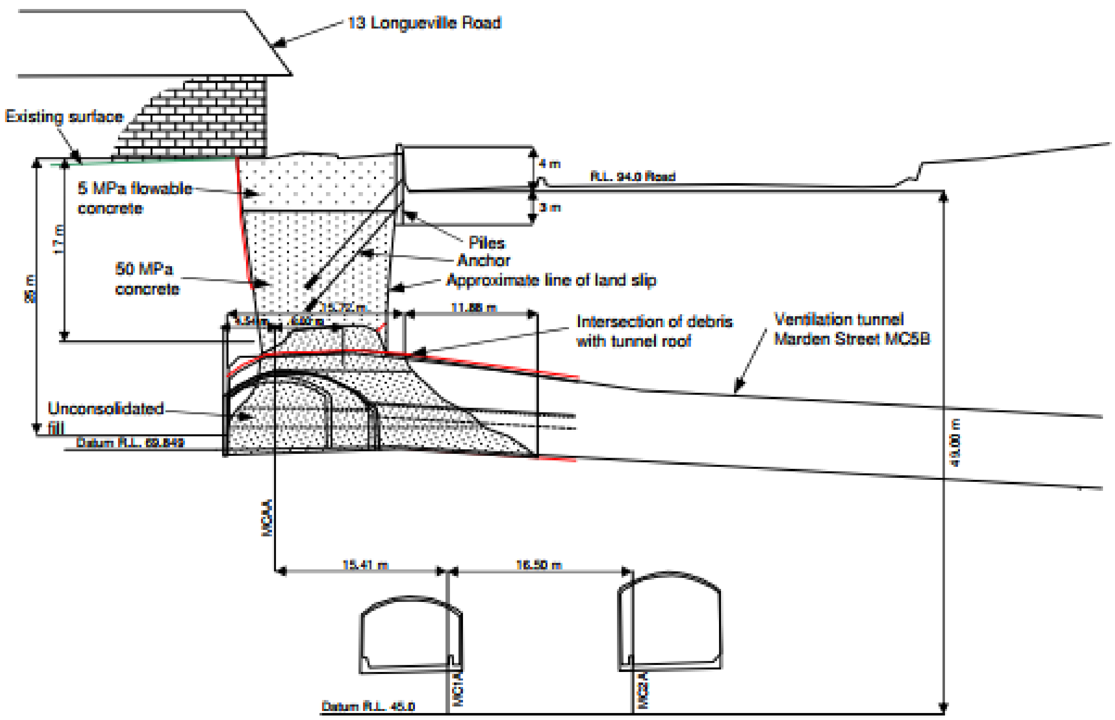


Figure 3: Vertical section through the collapse site following the concrete pours (Brown 2006)

Although there were all sorts of people not directly associated with the Project, both in Australia and overseas including local politicians, who appeared to believe that they knew all about it and had established the causes of the collapse independently of any detailed investigation or specialist knowledge of the circumstances, I was gratified by the reception that my Report received from members of our profession. Of course, the matter did not end with the submission and acceptance of my Report. A number of legal cases of one type or another continued for several years after the event, no doubt to the great financial benefit of a large number of members of the legal profession.

CONCLUSIONS

A lesson from the LCTP case history that has been repeated in other cases in my experience, is that if given the opportunity free of the disputatious features of the Australian legal system, experts in geomechanics, and I'm sure in other engineering specialities as well, can generally agree on the technical issues involved if they are free to approach the discussion with goodwill and mutual understanding. The well-known and highly experienced geotechnical engineer, Dr Philip Pells, kindly gave me the benefit of his local knowledge and observations on the first of my underground visits during my LCTP inquiry. In a later case involving the collapse of part of another tunnel then under construction in Sydney, Dr Pells and I found ourselves on the opposite sides of an arbitration case. Under questioning from the arbitrator who was a retired Supreme Court Judge, we were able to quickly agree on the key technical facts of the case, on the basis of which Dr Pells drafted our joint responses to the arbitrator's written questions.

One of the strongly held views that I have developed over a long career in universities and in consulting is the value to our profession of detailed studies of case histories such as the LCTP. With this point in mind, I sought and gained permission to publish some details of my inquiry in a paper presented at the International Society for Rock Mechanics' International Symposium 2006 and the 4th Asian Rock Mechanics Symposium held in Singapore in November 2006 (Brown, 2006).

The conclusions drawn from my investigation as recorded by Golder Associates (2005) and Brown (2006) were:

(i) "Tunnelling and underground construction are always attended by a number of risks and uncertainties, mainly associated with the inherent variability of the geological structure and mechanical properties of the rock masses in which construction takes place.

(ii) During the excavation of the Marden Street ventilation tunnel, a near-vertical dolerite dyke (or pair of dykes), was intersected at a number of locations. Although dykes are known to exist in the sedimentary rocks of the Sydney region, this particular dyke had not been identified in the pre-construction geotechnical investigation. However, the dyke had been intersected previously during construction in ventilation tunnel MC5A and the main line tunnels MC1A and MC2A.

(iii) Because of the presence of two sets of orthogonal joints associated with the dyke and other jointing and faulting, the shale rock mass at and near the junction of the MC5B ventilation tunnel and the MCAA exit ramp was of poorer quality than had been anticipated in the design stage.

(iv) The collapse started near the north-west corner of the newly extended down drive of the MCAA exit ramp at about 1:38 am on the morning of 2 November 2005, and rapidly extended across the exit ramp face to the dyke in the crown. The fall propagated across the crown of the junction of the MCAA exit ramp and the MC5B ventilation tunnel to the east or south-east and included the dyke. The collapse propagated to surface in Longueville Road in 10-20 minutes.

(v) The collapse initiated with the fall of rock blocks in the north-west corner of the excavation as a result of unravelling under lack of lateral and normal restraint.

(vi) The ultimate failure mechanism was progressive, probably consisting of several stages (listed in the report).

(vii) The processes and methodology used in the design of the LCTP tunnels was in accord with best practice in Sydney and elsewhere, and the resulting designs were generally suitable for their purposes.

(viii) In the design stage, no special analysis of the MC5B/MCAA junction was carried out. However, because of the inevitable local variations in the geological and geotechnical conditions, it was recognised that it would be necessary to adapt the initial design, particularly the support provisions, to the conditions actually encountered during construction.

(ix) TJH has in place a series of appropriate and best practice processes for the safe and productive execution of the underground construction works on the LCTP. Some of the documents setting out these processes are models of their kind.

(x) Up to the time of the incident on 2 November 2005, the designs and processes in place had been executed in a highly professional and productive manner by a knowledgeable and dedicated workforce and their supervisors.

(xi) The collapse arose from a combination of factors that were not present together at any other location in the underground works on the project.

(xii) The factors causing the collapse were probably:

- the presence of the dyke providing a persistent, relatively low strength, near vertical discontinuity transecting the roof of the excavation in a strike direction that was closely parallel to the maximum effective span of the junction,
- the presence of orthogonal, closely spaced jointing associated with the dyke, reducing the already poor mechanical quality of the Ashfield Shale rock mass,
- the presence of faults with orientations such that, in conjunction with the dyke, the joints and the excavation boundaries, they could isolate blocks that were free to fall or slide from the excavation boundaries if not adequately supported,
- a large effective span with relatively low cover to rock head, and
- the level of support existing in the western side of the excavation at the time being inadequate to ensure the excavation's stability given the large effective span, the low rock cover, the presence of a persistent vertical discontinuity (the dyke) transecting the excavation, and the poor mechanical properties of the overlying rock mass.

(xiii) Water was not a cause of the collapse.

(xiv) The proximity of the Longueville Road retaining wall and its ground anchors to the crown of the MC5B/MCAA junction excavation may have contributed to the collapse by influencing the loads applied to the rock immediately above the excavation, or by weakening the rock mass, or both.

(xv) The preparation of the best possible longitudinal geological sections and/or progressive geological plans may have been of assistance in projecting conditions ahead of the face as excavation progressed".

My experience of preparing the paper by Brown (2006) and others was that, whereas the senior engineers in the companies involved were usually willing to see the material published, their lawyers and commercial and PR personnel were not so accommodating. As I said in that paper, technological innovation and advances in engineering have often been attended by failure of one type or another. Unfortunately, in many cases, the information contained in forensic reports such as mine may be protected by legal privilege and remain confidential so that the results cannot be published and the potentially valuable information that the reports contain never reach the engineering profession.

ACKNOWLEDGEMENTS

I wish to acknowledge that assistance of the following people, in particular, in organizing, carrying out, and reporting on, the inquiry summarized here: Martin Albrecht, Rob Bertuzzi, Rob Morphet, Philip Pells, David Saxelby, Tim Sullivan and Steve Wille.

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WESTERN AUSTRALIA CHAPTER

THE FIRST DECADES

The very first WA representative on the AGS National Committee was Dr Baden Clegg. Dr Clegg served for 3 years (1970-1972) and later in the decade, for another two years (1979-80). Dr Clegg was active on the WA committee for decades.

Two extracts from *Australian Geomechanics News* in 1981 and 1982 respectively (below), provide snapshots of the AGS committee and its activities at the time.

Vignette from *Australian Geomechanics News* 1981

WESTERN AUSTRALIA

Chairman: Bob Mather, Geological Survey of Western Australia, 66 Adelaide Terrace, Perth, W.A. 6000.
(09) 325 0262.

Hon. Secretary: Dick Lilly, Major Works Branch, Metropolitan Water Board, 629 Newcastle Street, Leederville, W.A. 6007.
(09) 420 2420.

Committee: Baden Clegg, Dennis Ford, Lester Goodram, Ray Gordon, Gerry Hoffman, Richard Jewell, Gill Marsh, Doug McInnes, Ian Smith and John Trudinger.

The Western Australian Group has about 30 members and generally organises 4 technical meetings per year. Of these, 3 are normal meetings with one or two invited speakers and one is a seminar with at least 4 speakers and a high degree of participation from the floor. The normal meetings take place at 6 p.m. and are usually held during the months of March, September and November and the seminar, at which a break for refreshments is provided, starts at 4.30 p.m. and continues into the evening on a date in June. Whenever possible, arrangements are made to include visiting speakers at regular or specially arranged meetings, sometimes in conjunction with another group.

The programme for 1980 started with a talk about the "Burns Beach Sewer Minitunnel" given in March by David Robinson, Project Engineer with McConnell Dowell, and Garth Gilmour, Perth Manager, Snowy Mountains Engineering Corporation.

In June at a combined meeting with the Institution of Engineers, Australia, "Specifications for Earthwork Control" was the topic with prepared contributions being made by Denholm Brown of Dames & Moore, Geoff Cocks of Main Roads Department, and Ross Simpson who is currently studying in the Civil Engineering Department of the University of W.A.

"Mine Tailings Disposal" was the subject for the September meeting at which Ken Webster, Engineer for Planning, Design and Investigation in the Public Works Department and Mike Scott, Manager, WLPU Consultants, Perth, were the speakers.

25 November, a meeting to which invitations were extended for case studies to be given, is both the Annual Meeting and a General Meeting. The subject "Cone Penetrometers for Site Investigations" will be presented by Charles Waterton and Doug McInnes of the Public Works Department, with contributions from others regarding local experience involving correlations between SPT, self boring pressuremeters and relative density data. At 5.00 p.m. prior to the formal part of the meeting there will be a demonstration of the Cone Penetrometer in the car park at 712 Murray Street, West Perth.

The West Australia Group was proud to produce its Newsletter No. 1 in June of this year. It is planned at this stage to produce two newsletters each year and to rotate the responsibility for each issue among the various organisations represented on the committee.

In addition to the normal Group activities, this year saw the formation of a special Geomechanics Research and Development Sub-Committee comprising Doug McInnes (convenor), Richard Jewell and Ray Gordon. As part of its objective of promoting Geomechanics Research and Development in Western Australia, questionnaires were sent out to survey past and present activity and obtain suggestions for future work. As a result of the very good response, a Geomechanics Bibliography in the form of a card index retrieval system of previously reported work on Western Australia geomechanics topics has been set up. A thesaurus of key words has been compiled to be used in conjunction with the bibliography. A copy of the bibliography has been deposited with the National Library. It is intended that the bibliography will be updated annually.

The tentative programme for 1981 is given below. Further details will be available later.

24 March	Pavement Design.
23 June	Rock Mechanics topic.
22 September	North West Shelf, Geomechanics Aspects.
24 November	Satellite Imagery and Geomechanics.

WESTERN AUSTRALIA CHAPTER

Vignette from *Australian Geomechanics News* 1982

WESTERN AUSTRALIA

The Committee of the Western Australian Group of the Australian Geomechanics Society for 1982 is as follows.

Chairman - Richard Jewell, Department of Civil Engineering, University of Western Australia, Nedlands, W.A. 6009; Telephone (09)380-3080

Hon. Secretary - Dennis Smith, Soil and Rock Engineering Pty. Ltd., 32 Delhi Street, West Perth, W.A. 6005; Telephone (09)321-5666

Committee - Baden Clegg, Geoff Cocks, Ray Gordon, Gerry Hofmann, Gill Marsh, Bob Mather, Richard Parker, John Trudinger and Charles Waterton.

One general meeting of the Western Australian Group has been held in Perth since the last edition of Geomechanics News.

On the 23rd March, 1982, Dr. F. Netterberg, Head of the Soils Engineering Group, Institute for Transport and Road Research, Pretoria, South Africa, gave a talk with title "Pedocretes in Road Construction and Salt Damage to Seal Coats". This talk is reported more fully in this issue in the section on Conference and Technical Reports.

The programme for the remainder of 1982 is:

13th June - An excursion to Wungong Tunnel

29th June - Westrail Ballast Research, a talk by Ian Duncan, Research Engineer with Westrail

28th September - Seismic Detection of Blast Induced Damage in Rocks, a talk by Chris Swindells, Engineering Geologist with the Geological Survey of W.A.

3rd November - Details will be advised later.

Meetings are held at 6.00 p.m. at 712 Murray Street, West Perth.

The local sub-committee formed to co-ordinate arrangements for the forthcoming Geomechanics Conference to be held in Perth in May, 1984, has been enlarged and it reports good progress.

There has been a fair response to a questionnaire sent out last year for information to help up-date a Geomechanics Bibliography. The Bibliography was prepared two years ago by a sub-committee formed to advise on research co-ordination.

AGS AWARDS IN WA

Dr Baden Clegg Award

The award perpetuates the memory of Dr Baden Clegg (1925-1999), who was a lecturer at the University of Western Australia for around 30 years until his retirement in the mid-1980s, and recognizes his lifetime achievement in the support and development of young geotechnical professionals. Dr Clegg was instrumental in the invention and development of both the Perth Sand Penetrometer and the Clegg Impact Hammer, both used extensively for compaction control in earthworks and flexible pavements.

The award is presented annually to a young geotechnical engineer or geologist (under the age of 35 years) for the presentation of an outstanding 15-minute seminar on a topic of interest to the wider geotechnical community.

The seminars are presented by three or four selected candidates, with judging by a panel of three experienced geotechnical professionals who assess the seminars for their technical content, presentation quality and presentation style.

GFWA Prize in Geomechanics

The GFWA Prize in Geomechanics is a prize sponsored by geotechnical and foundations contractor GFWA Pty Ltd and awarded by the AGS for the best paper presented by a final year student in the area of Geomechanics at Universities in Western Australia. The winner is chosen by a panel selected by the AGS WA Committee. Judging is done on the basis of the overall quality of the project and work, the quality of the written paper, and the standard of the presentation on the night.

EDITING AUSTRALIAN GEOMECHANICS

For nearly 18 years (1982-1999), the *Australian Geomechanics* journal was edited by various state teams. Western Australia performed this task in the years 1990 - 1992 with an editing committee comprising Charles Waterton (editor), Trevor Osborne, Colin Bradbury, Martin Press and Dennis Smith. The first editorial from this team is presented as a vignette from *Australian Geomechanics* 1991 at the end of this paper.

WA HISTORY 2003-2019

In the early 2000s the demand for iron ore to feed the steel mills in China caused the price of iron ore to soar from $US30 per tonne in 2003, to $US168 per tonne in 2011. During this time the race was on to get this now valuable commodity from mine to port for export. New iron ore mines started to be developed and others expanded, including Hope Downs, Yandicoogina, Area C, Solomon, Greater Brockman Valley, Mesa A, and Christmas Creek.

There was a sudden demand for geotechnical engineers, starting with fly-in-fly-out personnel for investigation of rail lines, process plants, tailings dams, haul roads, jack-up barge drilling for new port facilities, and thousands of beds at new construction camps. For an engineering consultant, winning a project was often more about *when can you do it*, rather than *how much will it cost*. This was the resource infrastructure boom of WA's north west.

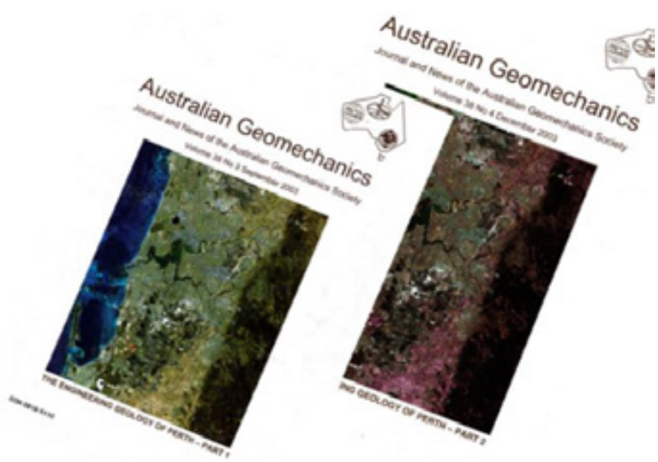
Western Australia's other major commodity, petroleum, also took off during this time with the development of several new oil and gas fields within the Carnarvon Basin. Onshore processing facilities were constructed including the Gorgon Gas Plant on Barrow Island, Wheatstone and Macedon near Onslow, and Pluto on the Burrup Peninsula.

It wasn't just resource projects constructed during the boom, the WA government capitalised and commissioned construction of several large infrastructure and property projects.

In what was a fantastic time to graduate from university and get a job, the WA engineering market was quickly exhausted leading to an influx of resources from interstate and overseas including the United Kingdom, Ireland, Asia, New Zealand, South Africa, and the Middle East. The population of Perth increased substantially during this time, rising by a staggering 25% in the 10 years to 2016. More people meant that more housing was needed and in true West Australian style, this meant building out instead of up.

The size of Perth exploded with residential developments springing up to the north and south of the city. Perth's built up area currently extends from Alkimos in the north to Mandurah in the south, a distance of more than 100km. Infill of areas closer to Perth with less desirable ground conditions, i.e. not sand, also began to happen.

The AGS in WA took advantage of the increased activity. There were new people in the industry and a real enthusiasm to contribute, give back, and to learn. In 2003 the WA Chapter of the AGS managed the creation of two journal editions dedicated to the Engineering Geology of Perth. The papers were prepared by local academics and practitioners and the publications have become the starting point for relevant information on Perth and WA soils and geology. The same topic was presented as a seminar in 2012. Another WA specific journal was published in September 2007 that included papers on specific design issues such as stormwater disposal through soakage.



In 2008 a seminar was run to educate engineers and geologists about the characteristics of the limestones of Western Australia and to provide case studies that demonstrated the engineering challenges presented by this material. The seminar included presentations by academics and local practitioners who had many years of experience in characterising and working with limestones in Western Australia.

In 2010 a workshop on ground improvement techniques was run to educate and inform geotechnical professionals, project managers and contractors on the latest ground improvement techniques currently being used both nationally and internationally. Expert advice was provided by industry contractors, academics, and consultants.

Other courses run regularly over this period include the ever-popular Soil and Rock Logging course run by Dr Fred Baynes, Geological Mapping, and Landslide Risk Assessment.

A SELECTION OF WA MAJOR PROJECTS

Narrows Bridge Duplication – The original Narrows Bridge, to connect Perth city to South Perth and the southern suburbs beyond, was built in 1959. By the mid – late 1990s the traffic volumes in Perth had increased significantly and the Narrows Bridge had become a bottle neck that restricted traffic flow during peak times. The bridge duplication required a replica structure that would double traffic capacity, provide dedicated bus lanes and look very similar to the original bridge. The main geotechnical challenges were associated with the adjacent reclaimed land fill areas, very close proximity to the existing bridge and the testing, installation, corrosion protection and monitoring of pile capacities for the 270 driven, 600mm diameter, steel tube foundation piles. One particular challenge was that the maximum driving energy that could be imparted into the pile head by the available hammer could not clearly remobilise the pile and confirm the pile ultimate capacity.

CD3 Port Hedland – In 1997 BHP Iron Ore commenced construction of the new third car dumper (CD3) in Port Hedland. CD3 is located between, and in relatively close proximity to, the earlier car dumpers 1 and 2. The location required temporary support of a 24m deep vertical excavation to enable construction of the permanent car dumper structure. A bored pile soldier pile wall, with three levels of high capacity drilled and grouted ground anchors, was adopted. Detailed monitoring of wall deflections and anchor loads was carried out to confirm that optimised design parameters had been adopted and to ensure that adequate anchor capacity was maintained. The difficult and highly variable ground conditions, significant excavation depth and high external ground water levels combined to make the drilling, grouting and testing of the ground anchors problematic.

Close monitoring and detailed onsite review of anchor construction and performance was required to ensure the eventual successful outcome.

Servetus Street – The original scheme to lower and realign the West Coast Highway through Swanbourne adopted cast-in-situ reinforced concrete gravity retaining walls. Major excavation would have been required for the solution with significant impact on adjacent roads and properties. A major permanent soil nail wall alternative was adopted that avoided over-excavation and provided a cost-effective solution. The ground strata intersected to lower the road comprised sand and variably cemented limestone. The flexibility of soil nail construction, in terms of nail lengths, reinforcement and spacing, was utilised to optimise the final wall details around the actual ground strata intersected.

Mining Boom - In the early 2000s the demand for iron ore to feed the steel mills in China caused the price of iron ore to soar from $US30 per tonne in 2003, to $US168 per tonne in 2011. During this time the race was on to get this now valuable commodity from mine to port for export. New iron ore mines started to be developed and others expanded including Hope Downs, Yandicoogina, Area C, Solomon, Greater Brockman Valley, Mesa A, and Christmas Creek.

New Metro Rail - Construction of the Mandurah Rail Line commenced in 2004 and was officially opened in 2007. The project involved construction of a new rail line in the median of the Kwinana Freeway that required major modifications to the Mount Henry Bridge, and cut / cover and bored tunnels from the northern end of the Narrows Bridge under Perth CBD through to Perth Station. A more recent extension to this project was the sinking of the Perth bus station. The bus tunnels were designed to support future overhead development as part of the development of Kings, Queens and Yagen Squares.

Forrestfield Airport Link – The Forrestfield Airport Link rail project commenced design and construction in 2016, and is due to be completed in 2021. The project involves twin 12m diameter bored tunnels from a new station at Forrestfield to the Bayswater junction, a distance of some 8km. New underground stations have been constructed at Perth Airport and Redcliffe.

PCEC - The Perth Convention and Exhibition Centre was constructed from 2001 to 2004 and is located within the Narrows Interchange reclamation area. This area was reclaimed using dredge placed sand and clay around 1960. The area also sits on, or close to, two palaeochannels of the Swan River. Settlements in the 24 years to 1997 have been recorded by MRWA to be up to 700mm beneath the location of the exhibition centre. The structure was piled to bedrock and settlement of the soils between the foundations has been an ongoing issue.

Elizabeth Quay – The development of Elizabeth Quay was a long time in the planning process and was finally completed in 2016. The project involved the excavation of over 150,000m^3 of soil to create the inlet. The edges of the inlet comprise 1km of 0.6m thick diaphragm walls installed to depths up to 19m, to support 4.5m of ground. Piles for the footbridge were installed to depths of up to 28m, socketed up to 6m into the Kings Park Formation.

New Perth (Optus) Stadium – Construction of the New Perth Stadium was completed in 2018. Significant pre-construction ground improvement works were required to support the new stadium that was constructed over landfill and soft Swan River sediments. Ground improvement included over 21,000m^2 of dynamic compaction and surcharge loading, 8,000m^2 of prefabricated vertical drains, 60,000m^2 of controlled modulus columns, and 2,700m^2 of sheet piling. The stadium itself is further supported on over 2,000 concrete piles driven to depths of around 35m.

Other recent major transport projects include Northlink WA – Extension of Tonkin Highway from Reid Hwy to Muchea, Gateway WA – Upgrade of Tonkin Highway, Leach Highway, and intersections at Roe, Leach, Horrie Miller, Kewdale and into the airport, and the Forrest Highway – a new freeway between the southern end of the Kwinana Freeway and Preston Beach.

RECOLLECTIONS – MATTHEW TUTTON
AGS - WA COMMITTEE 2000-2008

My involvement with the AGS spans 21 years. Looking back over this period there has been a massive amount of development across the state, the population of Perth has more than doubled, many of my mentors from the late 1990s have retired and a new wave of talented geotechnical professionals have come to WA and risen through the ranks.

It is fascinating to see how our knowledge of WA geology and geotechnics has also expanded over this time and during the 50 years since the inception of the AGS. In the short time span of the last 20 years our understanding of the presence and distribution of some of Perth's geological units has also increased considerably in response to the expansion and development of the city.

Soon after my arrival in Perth I saw a need for local Perth geotechnical and geological knowledge to be readily accessible to newcomers like myself and the AGS to fill this gap through a publication titled the *Engineering Geology of Perth*. Together with Bruce Bulley and Fred Baynes I was part of an editorial committee that saw the September and December 2003 editions of the *Australian Geomechanics* Journal dedicated to the Engineering Geology of Perth.

At the time the AGS WA Chapter was hosting annual themed local conferences and 2004 saw a day-long conference dedicated to the Engineering Geology of Perth, an opportunity to present the contents of the two editions. The conference was held in a boat shed on the Swan River and was followed by a boat trip down the river. Ray Gordon provided a commentary on the geology of the river banks and gave anecdotes on various engineering successes and mishaps relating to the various projects and structures that could be seen from the party boat. In all a very pleasant change from office routine.

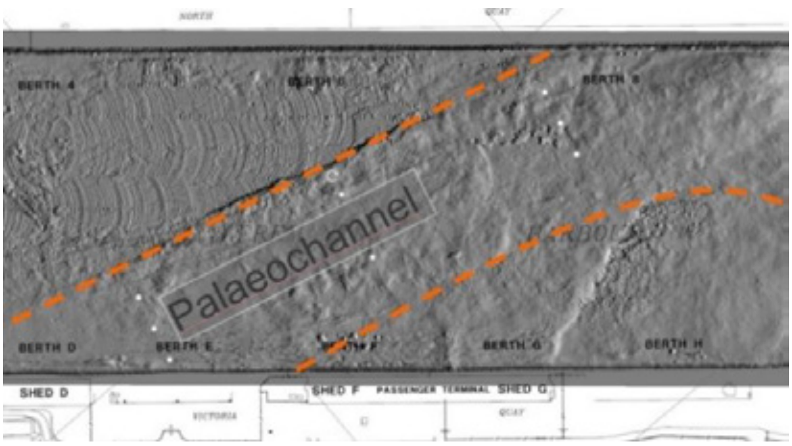
Ray Gordon contributed to the new publication and had a paper on the Swan River Palaeochannels, utilising data from historical investigations for the Narrows Bridge, The Causeway and the then recent investigations for the Convention Centre and Perth's Underground Railway.

I was also involved in the delineation and mapping of palaeochannels within the Swan River having developed the Geological Model for the then new Perth Underground Railway. In the Esplanade Station/Barrack Square area three palaeochannels relating to glacial periods that occurred approximately 150,000, 70,000 and 30,000 years ago, meandered, converged and in places were nested together in the same channel beneath the Esplanade area of Perth CBD. These same paleochannel segments became a focus for interest a decade later when the Elizabeth Quay project first gained traction.

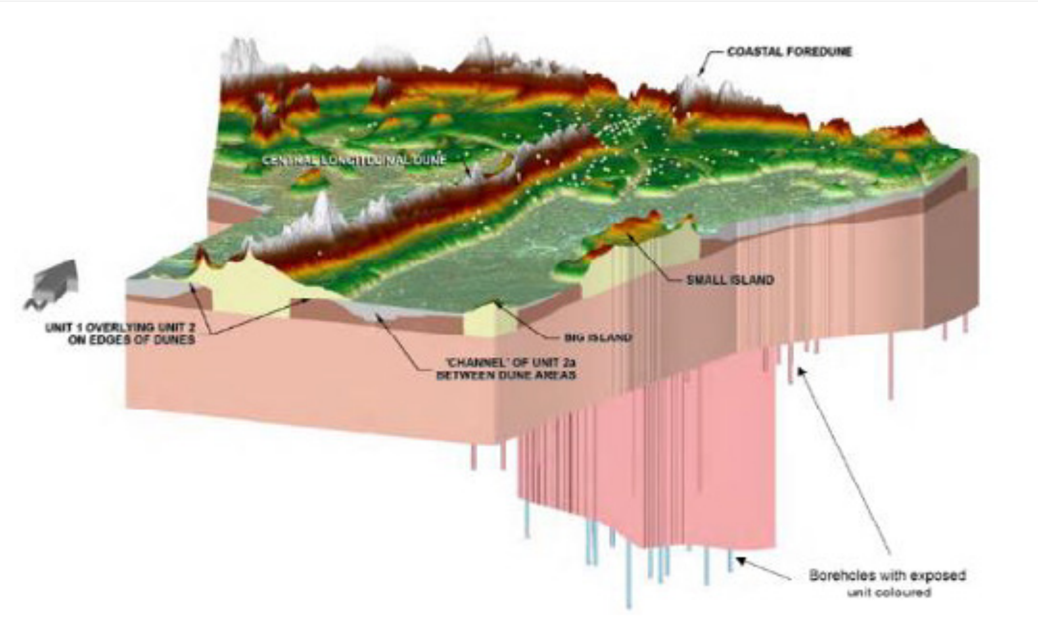
In 2004 I found myself again mapping palaeochannels as part of the ground model for the then planned deepening of Fremantle's Inner Harbour. This major project was completed in 2011. The task of delineating the palaeochannel was made somewhat easier than for the CBD area by an almost photograph quality side-scan sonar image of the harbour floor. The sediment filled channel contrasted with the adjacent limestone which had not been incised by the palaeochannel but instead displayed arcuate striations created by the cutting teeth of a dredging bucket.

As Perth developed and more projects came on line the subtle meanderings of the Swan River palaeochannels were further mapped. One particular paper of note was by Shane Greene in 2014 where he describes mapping the palaeochannel beneath the Burswood Peninsula and the site of the soon to be built Optus Stadium.

The new geology exposed through the construction of the Perth Underground Railway as it passes beneath the city and through three palaeochannels roused the interest of the Geological Survey of WA. Traditionally the clays and sand beneath the city had been mapped as Guildford Formation. The Guildford Formation is, however, strictly an alluvial fan deposit (based in its type section close to the Darling Escarpment) and as such there was motivation to rename the alluvial clay and sand strata in the city centre and the older palaeochannel infill deposits. This was similar to the re-naming and re-classification that had occurred in the UK when the former Woolwich and Reading Beds became the Lambeth Group. The Perth Formation and Swan River Formation became the proposed new nomenclatures and these names were registered on the Australian Stratigraphic Units Database. Papers were published and a 1 day conference was held to discuss the merits of the new names. Although the consensus at the conference was agreement to the renaming, time has demonstrated that the WA geotechnical community has not widely embraced the new nomenclature. This is possibly because the geological maps have not yet been updated and still show Guildford Formation underlying the city centre. The three letter acronyms (UGU, GFU, LGU etc.) relating to sub-units of the Guildford Formation devised as part of the Geological Model for the Perth Underground Railway, remain in common usage, even though the material is strictly associated with the Perth Formation.



One of the highlights of my time practicing as an Engineering Geologist and Geotechnical Engineer in WA has been my involvement in the Wheatstone LNG investigations. At its peak 100 people were present on site; in site laboratories, on drilling rigs, jack up barges etc.; and a further 25 involved in the office managing the laboratory testing program and reporting. I had specific involvement in developing the ground model and again found myself interpreting palaeochannels, this time through noting seabed features associated with former river delta. The huge data set from the mammoth-scale investigation afforded a rare opportunity to develop a complex 3D model. It was a privilege to work with many hard-working and immensely skilled geotechnical professionals both from our local AGS community and from those brought in from overseas to support us during this extremely busy period for our geotechnical community.

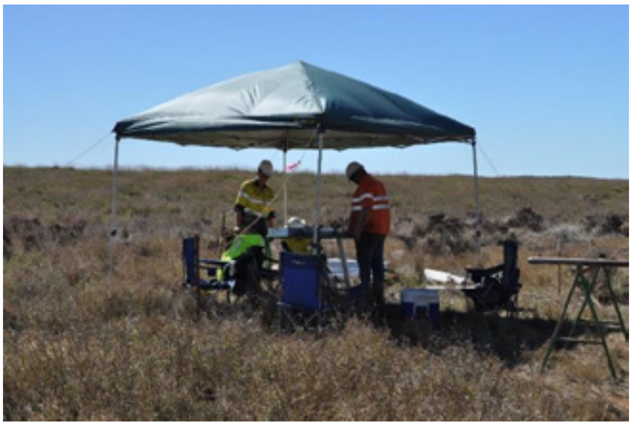


PHOTOGRAPHS OF VARIOUS WA PROJECTS

Jack up barge at Onslow

Narrows Bridge construction

Banded iron formation – Hamersley Gorge



Borehole logging in the Pilbara

Onshore drilling for the Wheatstone Project

Finucane Island, Port Hedland

Vignette from *Australian Geomechanics* 1990

EDITORIAL

This is the first edition of Australian Geomechanics to be edited by the Western Australian Group. We have of course approached the task with much journalistic zeal, aiming to at least emulate the high standards set by our predecessors in the editorial chair.

In this edition you will note a few changes of format. In the future you may see more, hopefully for the better, as we develop the a fore mentioned journalistic zeal.

One of the principal objectives of the new Editorial Panel is to narrow the gap that seems to exist between geotechnical people in the mining and civil engineering areas. Whilst recognising that such a gap is purely artificial, it is nevertheless there. This was underlined when the AGS WA Chairman only knew, *even by sight*, approximately half of the audience at a recent meeting addressed by Prof Barry Whittaker, whose special areas of interest include mining subsidence and slope stability.

The WA Group proposes to try to strengthen the bonds between the two groups and, to this end, we are scheduling several talks of mining interest. We are also investigating the possibility of setting up an AGS group in Kalgoorlie, where there is currently a great deal of interest in geotechnical matters, probably because of the recent open pit slope failures and the subsequent interest now being directed onto mining geotechnics by the Department of Mines!

It is in the interests of all of us to promote liaison between the "miners" and the "civil engineers" to overcome the perception that "the AGS is just for civil engineers" (heard during recent discussions with a group of mining people.) Will potential mining topic authors please take it on notice that their contributions will be gratefully received (and may even get "special consideration"!).

In 1991, we will embark on something of a first as we produce an edition containing a special feature dealing with "Waste Management". This topic appears to be an ideal vehicle to provide for this greater level of interchange between *the miners* and *the civil engineers*.

To support an expanded edition , we will be actively canvassing advertisers. This in itself will result in a somewhat changed format. Your comments in due course would be welcome.

These changes may be considered as representing something of the changes within Geotechnical Engineering in Australia as we see people like Professor Mark Randolph bringing a fresh approach to many aspects of the profession. This issue of Australian Geomechanics brings together some of these new developments as we present a major article on the UWA centrifuge and a guest editorial prepared by Mark Randolph.

Also in this issue we feature the 1989 E.H. Davis Memorial Lecture. This is particularly fitting as the award is a memorial to one of the pioneers of geomechanics in Australia whilst this lecture presents a new generation pioneering a new era. The subject of the lecture, "Geotechnical Aspects of the North West Shelf Project", represents the catalyst which proved to be so much a part of the development of the new facilities and faces which are now a part of our profession particularly in Western Australia.

It would be difficult to overestimate the part played by Dr Khorshid and Woodside Offshore Petroleum along with its joint venturers in developing local engineering and geotechnical skills through the foundations project for the North Rankin A platform.

The research and investigation associated with the project has significantly advanced our understanding of calcareous soils and elevated Australia to an eminent position in this area. To this, the success of the Calcareous Soils Conference in 1988 is ample testament.

Notwithstanding this position, we must remain forward thinking and move to meet the new challenges of this, the last decade of the twentieth century.

One of these major challenges must surely be the management of waste. In this generation we are presented with a two pronged challenge as we set about to manage the "mistakes" of the past as well as managing the mass of environmentally threatening products which are generated by our industrialised lifestyle. The whole style and quality of life which will be enjoyed by our children and other generations to follow may well depend upon how successfully we meet this challenge today.

Another challenge confronting all professions including geotechnical practitioners is the vexing question of legal liability. The "era" of waste management can only elevate the importance of this challenge as the consuming public seeks to place higher and higher levels of responsibility upon the shoulders of all professionals.

In this regard there are some promising signs that we may avoid the legal morass that seems to beset the professions in the United States. The Institution of Engineers, Australia has recently conducted a series of seminars around the country to bring engineers up to date with the present position and canvass the views of those directly involved.This exercise will be followed by the publication of a discussion paper later in the year. Hopefully this may present further light at the end of the tunnel.

Charles Waterton, Colin Bradbury, Trevor Osborne, Martin Press and Denis Smith. **Editorial Panel 1990**

Australian Geomechanics - December 1990

5

WESTERN AUSTRALIA CHAPTER COMMITTEES

Year	Chairman	Secretary	National Representative
1970-72			Dr Baden Clegg
1973-78			Mr Richard Jewell
1979-80			Dr Baden Clegg
1981-85			Mr John Trudigner
1986			Mr Geoff Cocks
1987			Mr Charles Waterton
1988-1990			Mr Charles Waterton
1991-93			Mr Ian Smith
1994			Mr Trevor Osbourne
1995-96			Mr Tad Szwedzicki
1997-98	A/Prof Martin Fahey	Mr Marc Woodward	Mr Trevor Osbourne
1999-2000			A/Prof Martin Fahey
2001-02	Dr Elio Novello	Mr Stuart P Masterson	Dr Elio Novello
2003	Mr Marc Woodward	Dr Doug Stewart	Mr Marc Woodward
2004	Mr Marc Woodward	Dr Doug Stewart	Mr Stuart Masterson
2005-06	Dr Doug Stewart	Prof Barry Lehane	Dr Doug Stewart
2007-08	Prof Barry Lehane	Dr Fiona Chow	Prof Barry Lehane
2009-10	Dr Fiona Chow	Dr Nina Levy	Dr Fiona Chow
2011-12	Dr Nina Levy	Dr Hugo Acosta-Martinez	Dr Nina Levy
2013	Dr Hugo Acosta-Martinez	Mr Colin Dickson	Dr Hugo Acosta-Martinez
2014-15	Mr Colin Dickson	Mr Michael Smith	Mr Colin Dickson
2016-17	Mr Michael Smith	Mr Stuart Ellis	Mr Michael Smith
2018-19	Mr Stuart Ellis	Dr Megan Walske	Mr Stuart Ellis

2010 TO 2019

DRILLING DOWN

Australia has been at the forefront of pile design theory and practice for many decades. While these piled foundations are not visible themselves, they support iconic structures across the country such as the Eureka Tower.

The late 2000s saw a boom in activity for geothermal resource development in Australia.

Oil & Gas development at the North West Shelf has seen construction of platforms, pipelines and other associated infrastructure venturing into new and challenging geological settings. As discussed in this chapter, the need to characterise and design for these carbonate sediments has led to continued advancements in offshore geotechnics in Australia from the mid-1990s until the present day.

North Rankin A Platform
Photograph courtesy Harry Poulos

GRAHAM SCHOLEY CHAIR 2010-11

AGS digs deep to make it seventh time lucky!

ICSMGE Sydney 2021

When I came to Australia in 1999 I was persuaded by my new colleagues to attend meetings of the Australian Geomechanics Society. In those days the Sydney meetings were held at Engineers Australia's Harricks Auditorium in a high-rise in upmarket Milsons Point. It was not surprising that developers got their hands on the site, pulling out the decrepit orange coloured theatre seats and converting the building into flashy apartments. The engineers of Sydney were shunted up the rail line to Chatswood!

The talk back then amongst the legends of our profession was of the Society's numerous unsuccessful attempts to bring the ultimate prize, the International Conference on Soil Mechanics and Geotechnical Engineering, to Australia. Five previous attempts had been thwarted, and if the stories are to be believed, sometimes to some devious and ingenious tactics by the competition! Fact or myths – I don't care, because as told by some famous characters of our profession over a glass or two of fine Australian wine they are wonderfully embellished stories that provided the inspiration for what came later!

The National Chair role fell my way in 2010, a privilege when I scanned the list of far more eminent predecessors. Not to be overwhelmed I delved into the Society's recipe book, otherwise known as the Constitution, to find out what I needed to do. What a remarkable document! Full credit to those who wrote it, creating a legal road map for the operation of the Society. This document is a must read for anyone who volunteers as a committee member at any level within the Society.

Talking about committee members, I was always a strong advocate for everyone on the committee to have a defined role. This gave each member a sense of purpose, belonging and ownership, leading to a greater commitment to the objectives of the Society.

By the time of my tenure, Peter Robinson, National Secretariat, had worked wonders to bring the Society to a position of financial strength. This was not without pain (for Peter and those exposed to Peter's wrath!). But what it meant was that the Society could fund projects proposed by our members that would reap benefits in accordance with the Society's mission and objectives, crafted with care into our Constitution.

In 2004 the Sydney Chapter had asked our members to apply for funding to bring into reality ideas that would benefit our members and society as a whole. This is when it first dawned on me how difficult it is to give money away effectively and above board. Nevertheless, an achievement from this campaign in Sydney was the publication by the Society of the map of structural features in the Sydney CBD that was developed by Phillip Pells, John Braybrooke and David Och. This map has a lasting legacy and is frequently seen on the office walls of members of our profession in Sydney.

When I think about some of the Society's achievements during the first decade of this century, the work on landslide risk management is top of mind. Contributors to this work were many but it is the dedication and persistence of Andrew Leventhal in promoting the cause that I recall. Much of this work was driven in response to the outcomes of the Thredbo Landslide enquiry. Those who work in landslide risk management know the Australian Geomechanics Journal Vol 42, No. 1, March 2007 as the definitive compilation of critical reference documents on the subject.

In 2011, the National Committee was approached by Stuart Masterson from Water Corporation in Perth. Stuart was seeking the support of the Society to update the outdated bible of our profession, AS1726 Geotechnical Site Investigations, for which the previous version was in 1993. The response of the National Committee was, as it was with other suggestions, that we expected this would take years to achieve and would require a truly passionate team to make it happen. History shows that the passion and commitment was there (long after my tenure) with the re-publication of AS1726 in 2017. I had very little to do with this and can only express my admiration to those people whose energy and commitment brought this to fruition.

The feeling of many of our members was that the purpose of achieving financial strength had been to position the society to underwrite major conferences, as these would benefit a broad swathe of our membership. The talk of our lack of success in past attempts to bring the International Conference to Australia irked. The fathers of our profession, including Professor Terzaghi himself, gathered for the first International Conference in Cambridge, Massachusetts in 1936. The time had surely come to bring the conference to Australia. In late 2011, in my last meeting as National Chair if I recall the timing correctly, the society voted unanimously to submit a bid for the 2017 conference, the Society's sixth attempt.

The voting process to decide the next venue of the conference is probably similar to that of football World Cup host country bid (but without the brown paper bags!). Each paid up member society of the International Society is entitled to one vote which is made at the International Society Council meeting held once every four years. Our strategy was to contact each member society in advance of the vote, promoting the benefits of hosting the conference in Australia. We leant on some of our most well respected leaders to help, including Professor Harry Poulos and Max Ervin. Our late entry to the contest did not help, up against China and South Korea as we were, and at the Council meeting in Paris in 2013 were out-voted in favour of Seoul, South Korea.

Not to be deterred, in 2014 the National Committee voted to bid for the 2021 conference, our seventh attempt! In Paris, our supporters had expressed their sorrow that yet again we had missed out. Our strategy for our seventh attempt was very straight forward - announce our intentions early and stymie the aspirations of other societies, which worked perfectly. At the Council meeting in Seoul on 10 September 2017, Professor John Carter enthusiastically presented our bid to the 80 member societies. The Council members were captivated and in the absence of any other contenders voted unanimously for the 20th International Conference to be hosted by the Australian Geomechanics Society in Sydney. Probably the most votes any bid has ever received!

So, in September 2021 the most prestigious event of our profession will finally come to Australian shores. For many years the members of the bid committee met by teleconference every 4 to 6 weeks, strategising and planning – Hugo Acosta-Martinez, John Carter, Guillermo Narsilio, Darren Paul, Mark Jaksa, myself with many others advising, supporting, advocating.

You may ask why we battled on and did not give up. We did it for our members, for the recognition of the Australian Geomechanics Society and to honour those Australian greats of our profession who through their previous efforts inspired the vision. At the time of writing, the conference is two years away, planning is well on track with many of you supporting us in different ways. All we need you to do is be there as a presenter, a participant, a sponsor or an exhibitor. When the next edition of this commemorative book is published in who knows how many years from now we hope that there will be some of you who can tell the stories about the Conference – some no doubt true, others steeped in Australian mythology fuelled by a glass or two of our fine wine.

2010-2019

OFFSHORE OIL AND GAS FACILITIES IN THE NORTH WEST

Mark Randolph is Professor of Civil Engineering in the Centre for Offshore Foundation Systems at the University of Western Australia. His research interests range across foundation engineering, particularly piled foundations, and offshore geotechnics.

He has co - authored two books, "Piling Engineering" and "Offshore Geotechnical Engineering", and some 300 journal articles. He interacts closely with industry, both in research and as a Technical Advisor within Fugro. He is a Fellow of several learned academies including the Royal Society in the UK.

PROFESSOR MARK RANDOLPH

INTRODUCTION

The first offshore oil and gas platform off the North-West coast of Australia was Woodside's North Rankin A platform, which started production in 1984. Since then, nearly 100 separate facilities have been developed, but with an enormous burst of major projects being developed concurrently over the last decade, including Pluto, Gorgon, Jansz, Wheatstone (see Figure 1) and - in the Timor Sea - Prelude and Ichthys, with others such as Scarborough, Browse, Crux and Barossa at different stages of feasibility assessment and front end engineering design. While the early platforms were fixed to the seabed in water depths of up to about 130 m, they were soon joined by deeper water floating facilities, particularly where the fields contained significant quantities of oil.

A step change occurred in the first part of this century with the development of the Greater Gorgon field, operated by Chevron, which comprises reservoirs towards the edge of the continental shelf in 200 m of water, but also the Jansz and Io fields beyond the shelf break at ~1200 m water depth.

The massive expansion of oil and gas facilities in Australia's Northwest has been accompanied by a corresponding growth in offshore engineering expertise in Perth, including the particular focus for this article, offshore geotechnical engineering. I have had the pleasure to be closely involved with this development, I hasten to add more by good luck than any deliberate plan, but it has certainly proved 'life-defining' in respect of my family's decision to move to Perth in 1986 and to settle there.

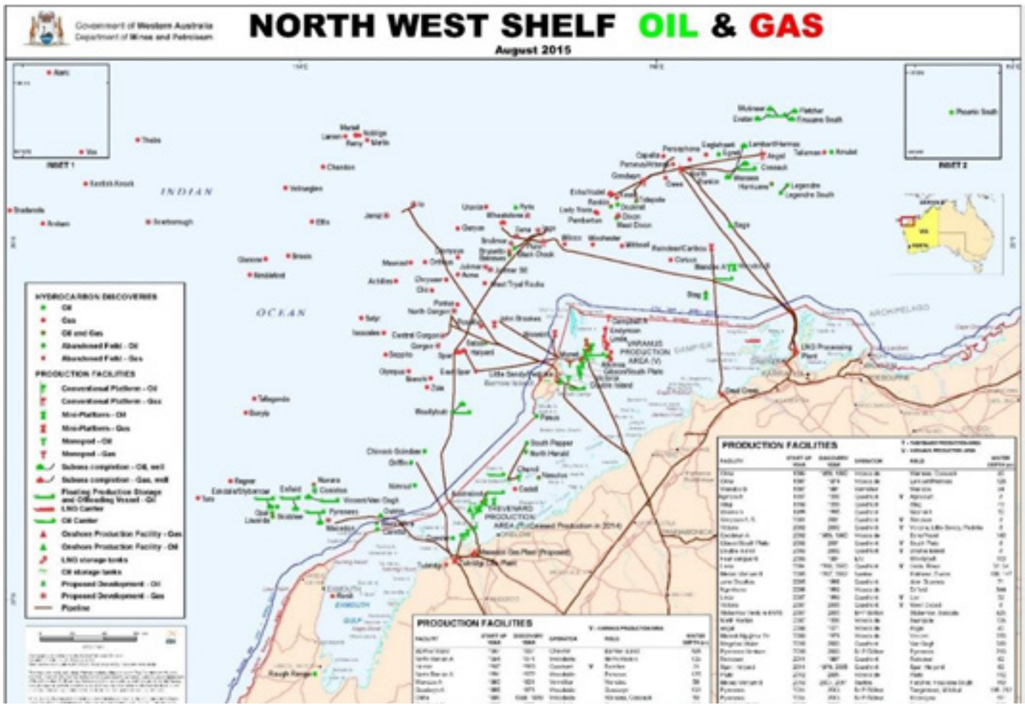


Figure 1: Map of offshore oil and gas facilities off the north-west coast [http://www.dmp.wa.gov.au/Documents/Petroleum/PD-SBD-GEO-105D.pdf]

The story below discusses some of the geotechnical challenges that have arisen, highlighting the Gorgon project in particular, while in parallel touching on the parallel developments in academia and the geotechnical consulting industry.

CHALLENGES OF CARBONATE SEDIMENTS

My first involvement with the challenges of foundation design in the carbonate sediments that predominate around Australia's coastline came while I was still resident in the UK, following the rather dramatic free-falling 'driven' pile installation for North Rankin A (NRA) platform. At that stage I was consulting for BP, one of the joint venture partners, and had my first visits to Perth as part of the review of the pile foundations. As described in greater detail by Senders et al. (2013), "*the piles typically free fell between 0 and 64 m and then again between 72 m and 114 m*". The piles had been designed using conventional API approaches for piles driven into silica sand, but without due consideration of the highly compressible (and crushable) nature of carbonate sediments that arises from the shape of the grains (see Figure 2).

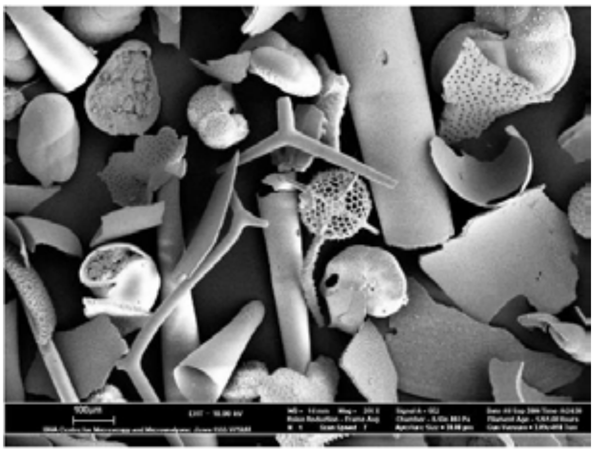


Figure 2: Angular and crushable nature of carbonate sediments

The crushability, together with high friction angles associated with the grain angularity, appears to allow stable arching of soil around the pile, with very low normal effective stresses and shaft friction. Typically design values for the shaft friction of piles driven into such sediments are limited to 5-10 kPa, even at a depth of 100 m. The main remedial actions included the injection of a Shell-developed product, Eposand, into the sediments beneath the pile tips – no mean feat in itself, given the 120 m water depth – and then excavating four under-reamed bell foundations within the treated zone (see Figure 3).

The experience at North Rankin A convinced Woodside of the need to develop local expertise in the engineering of calcareous sediments, resulting in two significant initiatives that were led by Woodside's Dr Mohamed Khorshid. The first of these was the organisation of an international conference on this topic, which was held in Perth in 1988 (Jewell & Khorshid, 1988). The second was to develop a partnership with the emerging geomechanics group at the University of Western Australia, led at that time by Dr Richard Jewell supported by Dr Martin Fahey and myself (from August 1986).

Following NRA, later pile foundations on the North West Shelf have generally been designed as a two-stage foundation comprising a driven primary pile, penetrating uncemented sediments that might otherwise flow into a drilled borehole, together with a grouted insert pile installed below the tip of the driven pile (Senders et al. 2013). A major focus initially of the collaboration between Woodside and UWA in the late 1980s was on developing design approaches for grouted piles in the weakly cemented calcarenite existing below about 120 m at NRA and the nearby Goodwyn platform then being designed.

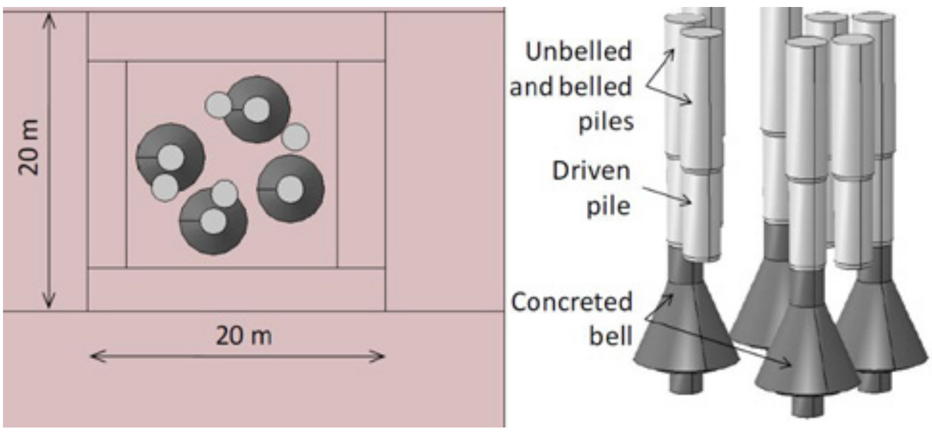


Figure 3: Remedial bell foundations installed at NRA (Senders et al. 2013)

2010-2019

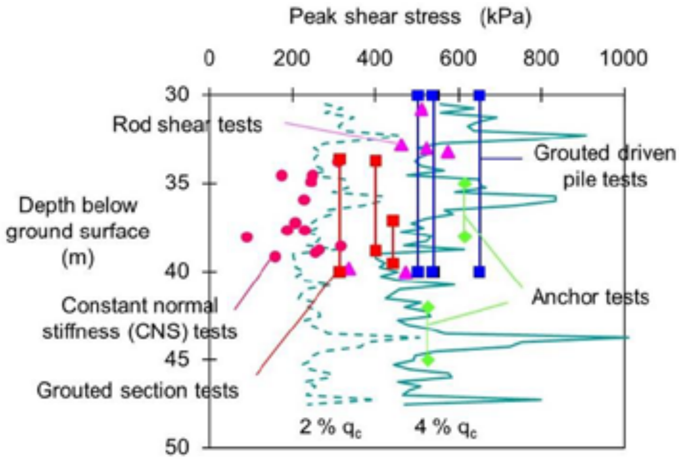


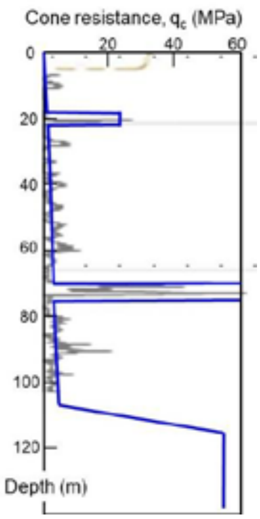
Figure 4: Overland Corner: cone resistance and pile shaft capacity in weakly cemented calcarenite

These studies ranged across laboratory tests, including cyclic rod shear tests that were subjected to over one million cycles, a major set of field tests performed in weak limestone at Overland Corner in South Australia (Fahey et al. 1992, Randolph et al, 1996), and calibration using experimental data of software, RATZ (Randolph & Jewell 1989, Randolph 1994), to simulate cyclic axial loading of a pile in sediments with a potentially brittle interface.

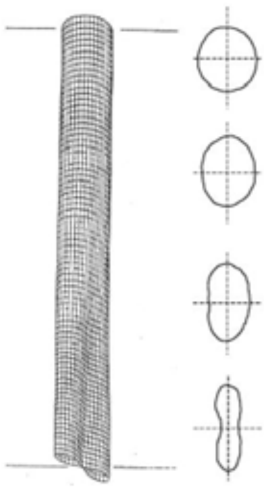
Typical strengths of the relevant cemented zone in which the grouted insert piles were founded are illustrated in Figure 4. This figure summarizes various test data from Overland Corner, ranging from constant normal stiffness (CNS) tests, rod shear tests and field testing of sections of grouted pile and also longer post-grouted driven piles (Randolph et al. 1996).

The background profile of cone resistance (scaled to overlie the data) indicates shaft friction values of 2-4% of q_c, the lower limit of which formed the basis of design at that time. Over the intervening years, increasingly sophisticated approaches have been developed for the design of grouted piles in calcarenite, including a proprietary enhancement of RATZ and adoption of CNS tests, both monotonic and cyclic, as the basis for quantifying load transfer parameters (Erbrich et al. 2010a). However, the field tests at Overland Corner remain a cornerstone for validation of the approach.

Ironically, the first platform to adopt the two stage piled foundations, Goodwyn, which was installed towards the end of 1992, suffered a rather different form of problem. The 2.65 m diameter primary piles were designed with a wall thickness of 45 mm, so diameter to wall thickness ratio of 59.



(a) Cone resistance profile



(b) Pile distortion (below~75 m depth)

Figure 5: Cone resistance profile and distorted pile shape at Goodwyn platform

Although this is relatively high, easy driving was expected, just as at NRA. In practice, however, 16 of the 20 piles underwent severe distortion over the bottom 20 to 40 m, preventing drilling out to install the grouted inserts (see Figure 5b). The main trigger for the distortion was the rather strong cemented layer at 75 m depth possibly exacerbated by minor damage to the pile tip occurring during handling and stabbing the piles through a seabed template (Senders et al. 2013). The piles were eventually remediated sufficiently, using a combined process of crocodile jacks and internal pressurisation (Barbour & Erbrich 1994), to allow construction of the grouted insert piles as originally planned. This type of pile collapse will be discussed further later in the paper.

A STEP CHANGE – OFF THE SHELF

The development of the Greater Gorgon field in the period 2010-2015 introduced a significant change in focus of offshore activities in respect of the Jansz and Io reservoirs, which were in water depths of around 1200 m. The development adopted a subsea approach, with relatively large manifolds near the well locations to direct the flow from the wells into an export pipeline to the processing plant at Barrow Island.

The most significant challenge of the development lay in routing the export pipeline up the steep scarp separating the Gorgon field (200 m water depth) and the deep water Jansz and Io fields. The nature of the scarp is illustrated graphically in Figure 6 (Hengesh et al. 2012).

In addition to finding a suitable route up the scarp itself, the geohazard risks to the pipeline from submarine landslides and consequential debris flows and gas expulsion features needed to be assessed.

The scarp appears to have resulted from a seismic event or other trigger that caused a major slope failure some 40-45 thousand years ago, and contains localised zones where the gradient is close to vertical with significant drops of ~10 m. Sediments above and below the scarp are essentially normally consolidated, and there is no evidence of cementation per se in the sediments on the scarp itself, other than due to interlocking. Near surface strengths reach 20 kPa, with peak friction angles close to 50° (Zhang et al. 2015). Assessment of the natural slope stability was therefore extremely difficult, faced with this combination of steep gradients and relatively low shear strengths. Geochronology played a major role in the assessment, evaluating historical slope failures in terms of the deduced ages and estimated slope conditions at the time of failure.

An innovative solution for the scarp crossing was arrived at, as indicated in Figure 7, which shows the main 30″ production pipeline and smaller 8″ and 6″ lines for monoethylene glycol (MEG) and utilities (UTL) respectively, descending the scarp between water depths of about 500m and 800 m. (Zhang et al 2015). In order to alleviate curvature over the upper part of the scarp, areas of sudden changes in gradient were trenched using mechanical grabs; water jetting tools were also trialled but were found less robust. The lower part of the scarp was bridged by a suspended section of pipeline, aptly referred to as the 'super-span', some 270 m long.

Sophisticated engineering studies were undertaken to address design issues associated with the super-span, including fatigue due to VIV induced by transverse currents and embedment at the lower end of the span due to pipe weight, and cyclic loading from 'slugging' of mixed phase pipe contents. These and other issues are discussed in greater detail by Zhang et al. (2015).

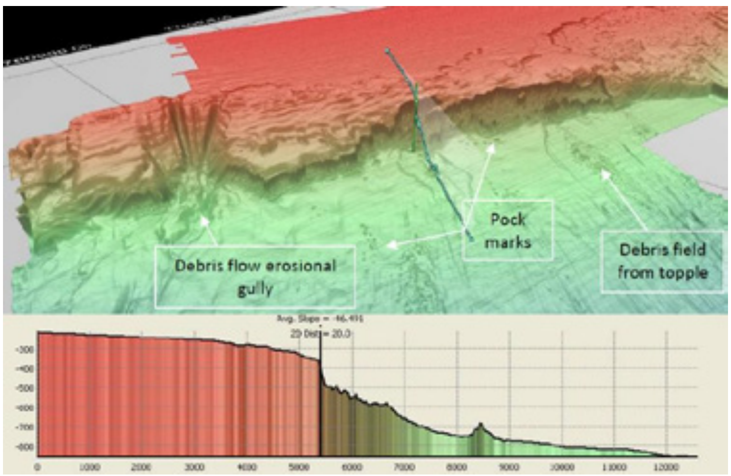


Figure 6: Perspective view and bathymetric profile of the Gorgon landslide scarp (Hengesh et al. 2012)

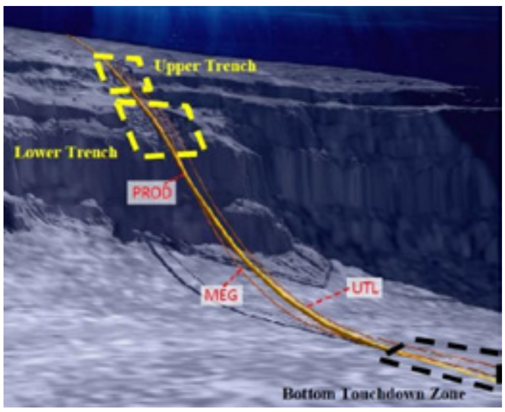
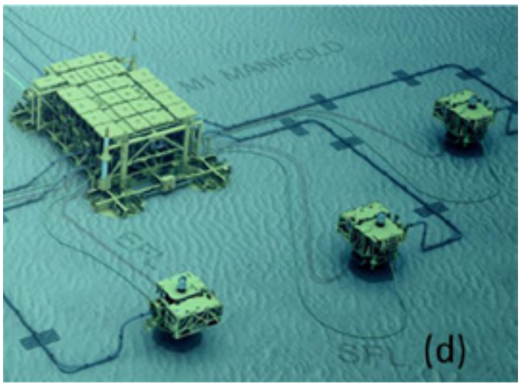


Figure 7: Overview of Gorgon scarp crossing (Zhang et al. 2015)

Although the scarp crossing was a major focus for geotechnical design, there were further technical challenges at both the upper (Gorgon) and deep water (Jansz, Io) locations in respect of the design of the various foundations, on-bottom pipelines and risers for the subsea system. Figure 8a shows a schematic of well-head units connecting to a main manifold at Gorgon, while Figure 8b gives an indication of the size of the manifolds and foundation systems. In this case the foundation was around 40 m × 30 m in plan with skirts of 3 m, designed to support a manifold weighing over 900 tonnes in air (Broadway & Tachoires 2016). The net bearing pressure to be sustained, although not high, needs to be considered in the light of the shear strength profile, with average strengths over the upper 10 m of around 15 kPa.

Accurate determination of shear strength in the upper 10-20 m of the seabed relies heavily on in situ penetration testing, since it is difficult to obtain high quality undisturbed samples of the low strength material. Over the last twenty years, there has been increasing use of so-called 'full flow' penetrometers, such as the T-bar (Stewart and Randolph 1994) and ball penetrometer (Randolph 2004) to supplement different size cone penetrometers (Figure 9b). In soft sediments full-flow penetrometers have increased accuracy relative to the cone by virtue of the projected area and reduced corrections for overburden stress. They also allow cyclic penetration and extraction in order to measure the sensitivity of the soil.

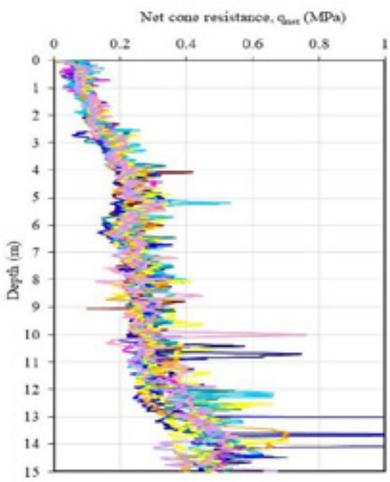
Figure 9b shows data from two cyclic T-bar tests, which show a sensitivity of about 5, although values well in excess of 10 have been measured in some near-surface carbonate sediments (Watson et al 2019).



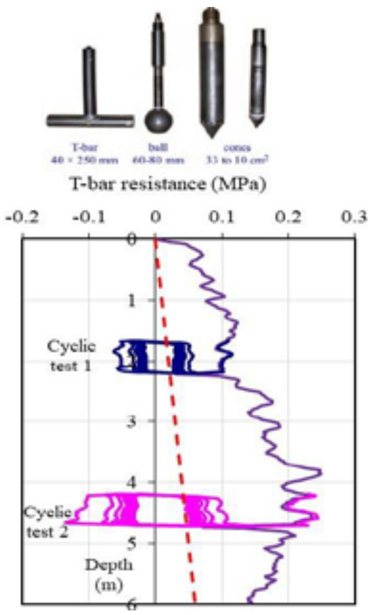
(a) Schematic of Gorgon subsea manifolds (Watson et al. 2019)

(b) Jansz manifolds during load out (Broadway & Tachoires 2016)

Figure 8: Subsea layout and Jansz manifolds for Greater Gorgon development



(a) Profiles of net cone resistance



(b) Penetrometers and cyclic T-bar data

Figure 9: In situ penetration testing at Jansz and Io deep water locations

Design of shallow mudmat foundations is a complex process, needing to take account of fully three-dimensional loading transferred from infrastructure connected to the manifold, such as spool pieces and export pipelines. Apart from the weight of the superstructure and foundation, loads arise (a) from slight mismatch of flanges during connection; (b) from current loading; and (c) from pressurisation and thermal expansion and contraction of connected pipelines. The foundation needs to be optimised to avoid excessive size and weight, which increase fabrication and installation costs, so beneficial changes in soil strength due to consolidation must be considered as well as strength reduction due to cyclic operational loading.

Balancing the beneficial effects of consolidation are potential serviceability issues arising from foundation deformations relative to connected infrastructure, especially settlements due to consolidation under the applied bearing stress and from dissipation of excess pore pressures generated during cyclic loading. Simplified analysis approaches to address design performance from the perspective of capacity, in particular catering for six degree of freedom loading and the benefits of consolidation, have been developed in partnership with industry (Feng et al. 2014, Gourvenec et al. 2017). For commercial design, where more complex soil stratigraphies are encountered and hundreds of different load cases must be addressed, cloud computing has proved a very efficient and cost-effective approach (Doherty et al. 2018).

LEGACY

It is fitting to end this paper with some comments on the broader picture of offshore geotechnical engineering and how lessons learnt from the early offshore platforms have been translated at both national and international level. As noted earlier, one of the great strengths in developing scientific approaches to the treatment of Australia's offshore carbonate sediments has been the close symbiotic relationship between industry and academia, principally the Centre for Offshore Foundation Systems (COFS) at UWA. The latter was funded as an Australian Research Council Special Research Centre over the period 1997-2005, by the WA State Government as a Centre of Excellence 2007-2012 and as a node of the Australian Research Council Centre of Excellent in Geotechnical Science and Engineering (CGSE) 2011-2017.

The main industry partner during the rapid expansion of the North West Shelf was the specialist offshore geotechnical consultancy, Advanced Geomechanics (AG), over the period 1994, when it was founded, to the end of 2013 when it was acquired by Fugro. AG provided the link to ultimate clients such as Woodside, Chevron and the Gorgon Joint Venture, Inpex, Shell and many others, but for many years all advanced laboratory and centrifuge model testing was conducted in the facilities developed by COFS. UWA staff such as myself, Richard Jewell and Martin Fahey were external Directors at AG, as was Professor John Carter from the University of Sydney (later from the University of Newcastle). Dr Mohamed Khorshid was the founding Managing Director of AG, followed by Dr Phil Watson (one of my PhD graduates) who took over in 2008. Other Directors of AG included Paul Hefer, Dr Steve Neubecker, Dr Ian Finnie and Dr Hackmet Joer (the last three all ex-UWA PhD graduates or early career academics), but the main credit for all technical developments and the resulting high quality consulting advice to industry rests with the Technical Director, Carl Erbrich.

It is perhaps invidious to list key personnel in the above manner, but this is as much their story as mine. The rapid growth in offshore facilities associated with the North West Shelf and Timor Sea necessitated expansion of consultancies such as AG, and a high proportion of staff were recruited from UWA graduates, mainly at PhD level. These and other highly qualified staff remain in Perth, notwithstanding the five year industry downturn that started in 2014, but is now spread among Fugro and the Perth offices of Arup and the Norwegian Geotechnical Institute.

The early lessons in pile-soil interaction from North Rankin A and Goodwyn have since been applied in several other developments, not just with respect to grouted pile design (Erbrich et al. 2010, Senders et al. 2014), but also in methods to control free-fall of driven piles through uncemented carbonate sediments and to avoid pile tip distortion and the onset of extrusion buckling during driving through cemented layers. The 5.5 m diameter anchor piles for Shell's Prelude floating LNG development, a world first, and Inpex's adjacent Ichthys floating production system, incorporated devices to limit free-fall speed through uncemented carbonate silts, but also thickened driving shoes and cruciform internal stiffeners to avoid pile tip damage during driving through cemented layers (Frankenmolen et al. 2017, Erbrich et al. 2017). Design of the piles relied on the state-of-art numerical tool, BASIL, developed originally for suction buckets in the North Sea (Barbour & Erbrich 1995, Erbrich et al. 2010). International reach of this software has extended to European offshore projects, including the extrusion buckling failure of piles driven into dense sands at BP's Valhall field in the North Sea (Alm et al. 2004). The frequency of this type of failure has increased in recent years as a result of the large diameter, high diameter to wall thickness ratio, piles being used to support offshore wind turbines in the North and Baltic seas.

On a final note, reverting to the involvement of academia in industry, one of the main geotechnical legacies to have emerged over the last thirty years has been the National Geotechnical Centrifuge Facility managed by COFS at UWA. The facility, which comprises two beam and one drum centrifuges, was recently acknowledged among Australia's 100 most notable engineering achievements over the last century (Engineers Australia 2019). Its development has relied heavily on the offshore industry for generic and site-specific studies of foundation, pipeline and anchor systems, including design studies for Gorgon's super-span and other ground-breaking solutions such as sliding foundations for pipeline terminations (Deeks et al. 2016, Watson et al. 2019). The projects have underpinned the financial security of COFS, which has flourished for over 25 years, particularly under the able directorship of Professors Mark Cassidy (2006-2017) and Christophe Gaudin (2018 to date). Whether it continues to survive university politics is another question altogether!

ACKNOWLEDGEMENTS

This paper has drawn on activities of the Centre for Offshore Foundation Systems (COFS), supported variously by the Australian Research Council, the WA State Government and through the Fugro Chair in Geotechnics, the Lloyd's Register Foundation Chair and Centre of Excellence in Offshore Foundations and the Shell EMI Chair in Offshore Engineering. Grateful acknowledgement is made also to the many UWA colleagues who have contributed to this, and to numerous colleagues in the former Advanced Geomechanics and now Fugro.

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Vignette from *Australian Geomechanics*, December 1990

GUEST EDITORIAL

POSTGRADUATE EDUCATION OF GEOTECHNICAL ENGINEERS

Professor M. F. Randolph, Department of Civil & Environmental Engineering
The University of Western Australia

I was very pleased to be invited to contribute this Guest Editorial. It comes at an exciting and challenging time, both for me personally, and for engineers and teachers in the geotechnical profession throughout Australia.

There have been a number of initiatives in recent months in connection with the education of engineers, particularly at postgraduate level. A key element of the planned Co-operative Research Centres, which are discussed further below, will be postgraduate research training. This is intended to redress the current paucity of scientists and technologists educated to Masters or PhD level. A parallel move has come from the Institution of Engineers, with the proposed requirements for Continuing Education of graduate engineers. This initiative, although it appears to undervalue the longer term role of higher degrees, clearly acknowledges the insufficiency of even a four year Bachelor degree in today's specialist and changing engineering world.

Somewhat at odds with the perceived needs for postgraduate training referred to above, the Institution has also recently introduced a requirement for a minimum quantity of 'management' topics within undergraduate degree courses. Initially, the interpretation of management topics is to be relatively broad, including any elements of a course that address communication and design skills. However, there appears to be a background trend towards explicit management courses, such as those more usually encountered in postgraduate MBA courses. These courses would be feasible in a five year engineering course, such as the double degrees in Engineering and Management or Commerce that are currently available, but would inevitably dilute the technical content of standard four year degrees.

Rather than stipulating a minimum level of management content in undergraduate engineering courses, the Institution of Engineers should judge individual courses on the overall quality of the graduates produced. Courses that produce highly skilled technical engineers who, if they so wish, may proceed to higher level specialist education, should not be penalised in the interests of uniform mediocrity.

Continuing education is essential for engineers, both to acquire formal management skills and to update technical skills. Higher degrees should play a major role in this area. In Europe and the North American continent, a Masters or PhD degree is considered essential in order to specialise in geotechnical work. The Australian Geomechanics Society should be lobbying for a similar standard. In the past, potential postgraduate students have been deterred by the lack of support from government, in terms of the level of scholarships, and from industry, in terms of salary levels that reflect the additional training. The situation is now changing. Recent increases in the value of postgraduate scholarships, and the introduction of industry-linked awards, have improved the terms under which higher degrees may be earned. The industry should now seize this opportunity to encourage graduates of 2 - 5 years experience to return to university for further specialist education.

The Federal Government has recently launched a scheme for Commonwealth funded Co-operative Research Centres. The principal goal of these centres, which will concentrate on science and engineering, is to provide further links between industry and research groups. Particular emphasis has been placed on postgraduate training through higher degrees, with direct involvement of postgraduate students in industry.

It is interesting to contrast the role of geotechnical specialists in two key industries in Australia - offshore engineering and mining. This issue of Australian Geomechanics contains Dr Khorshid's E.H.Davis Lecture, which describes the geotechnical experience on the North West Shelf. The early design for the North Rankin 'A' foundations was dominated by European and American consultants. The need for remedial treatment of the foundations initiated a major programme of research on calcareous soils throughout the world, but with a high percentage of that research being carried out in Australia. As a result, world expertise on calcareous soils now rests in Australia and foundation design for the subsequent Goodwyn platform was performed primarily by Australian engineers. The programme of research underwrote many PhD theses and there is now an appropriate pool of specialists within the industry.

By contrast, the mining industry has a woefully low presence of geotechnical engineers. In Western Australia, a large percentage of gold mines are designed with no specialist geotechnical input and suffer accordingly from high rates of failure. There has also been a recent spate of failures of open-pit slopes. The financial consequences of these failures dwarf the remedial measures of North Rankin. There is an urgent need for a major re-assessment of geotechnical design in the mining industry, and for an increased level of postgraduate research training.

To summarise, geotechnical engineers have a major role to play in Australian society, particularly in the development of natural resources. As a body that has close connections with the Institution of Engineers, the Australian Geomechanics Society should lobby for increased training of geotechnical engineers. We should resist any reduction of technical content at the undergraduate level, and push for greater recognition of higher degrees in the realm of continuing education.

Australian Geomechanics - December 1990

6

SAM MACKENZIE CHAIR 2012-13

Who's who in the zoo – taming acronyms and setting our sights again on the ISSMGE international conference

Taking over from Graham Scholey was a tough act to follow. AGS was in good shape with over 1500 members and an enviable financial position. I didn't want to stuff it up.

An early challenge was understanding and developing our relationships with other organisations.

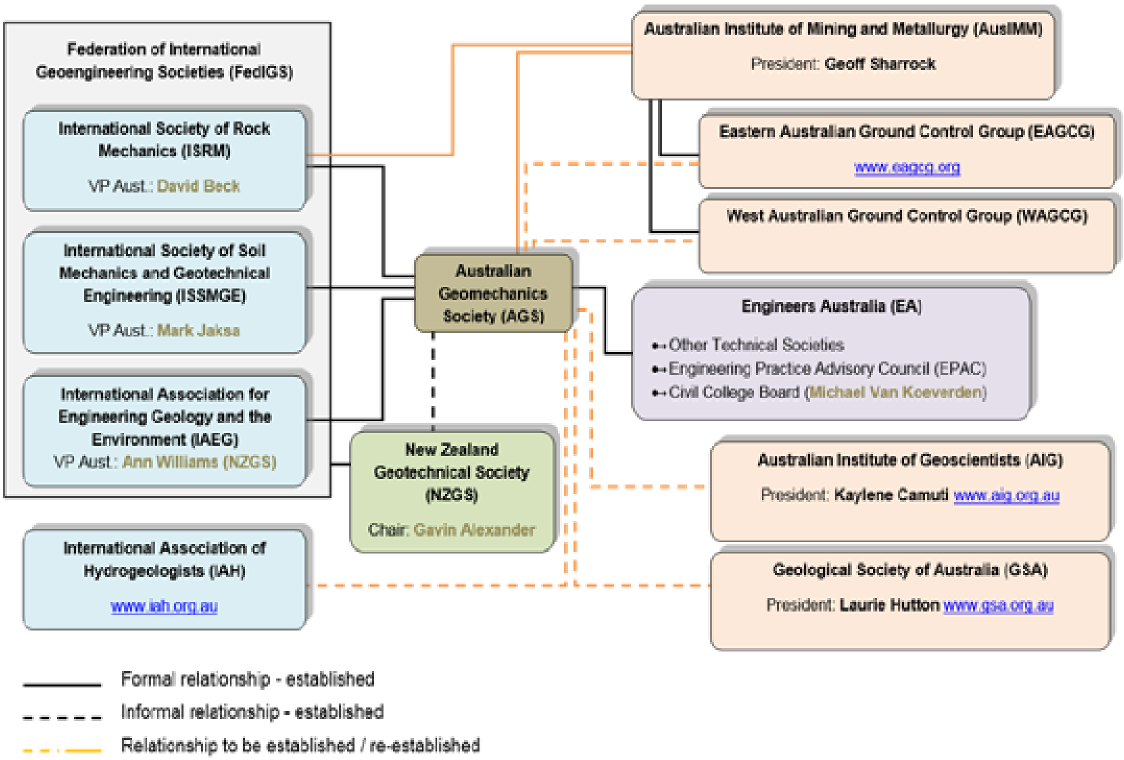
As anyone who has attended a National Committee meeting can attest to, acronyms are at plague proportions and it takes a while to work out how it fits together. The chart shown in Figure 1 helped.

Two relationships needing improvement were with our 'parents', Engineers Australia and AusIMM. While Engineers Australia knew we were their largest technical society, they had forgotten what we actually did. The mechanics in Geomechanics apparently causing confusion with mechanical engineering. AusIMM on the other hand didn't even know we existed and we really starting thinking about removing their logo from AGS documents.

Our participation in Engineers Australia's "Engineering Practice Advisory Committee" meetings went a long way to improving things. However, the tension between many of the technical societies and EA was telling and AGS were happy to be in the fray and putting our case forward for changes. Our financial security enabled AGS to be more independent than other technical societies and, for example, underwrite our own conferences such as ANZ 2012.

ANZ 2012 in Melbourne was a great success as a conference but also as an opportunity to lobby the ISSMGE board members about our bid for ICSMGE 2017, the International Conference on Soil Mechanics and Geotechnical Engineering. While we ended up missing out on 2017 to South Korea, our efforts in 2012 and 2013 laid the building blocks for the eventual 2021 conference win.

An excellent line up of international speakers continued through 2012 and 2013 with the following doing the rounds: Dr Robert Holtz, Dr Nick O'Riordan, Professor Brian Simpson and Professor Malcolm Bolton.



Flow chart showing the relationship between the AGS and allied organisations

ISSMGE President Professor Jean-Louis Briaud (R) and Sam McKenzie (L) at ANZ 2012

To assist Patrick MacGregor with editing the Journal the National Committee executive appointed Tanya Kouzmin as sub-editor in early 2012. This proved to be an excellent choice.

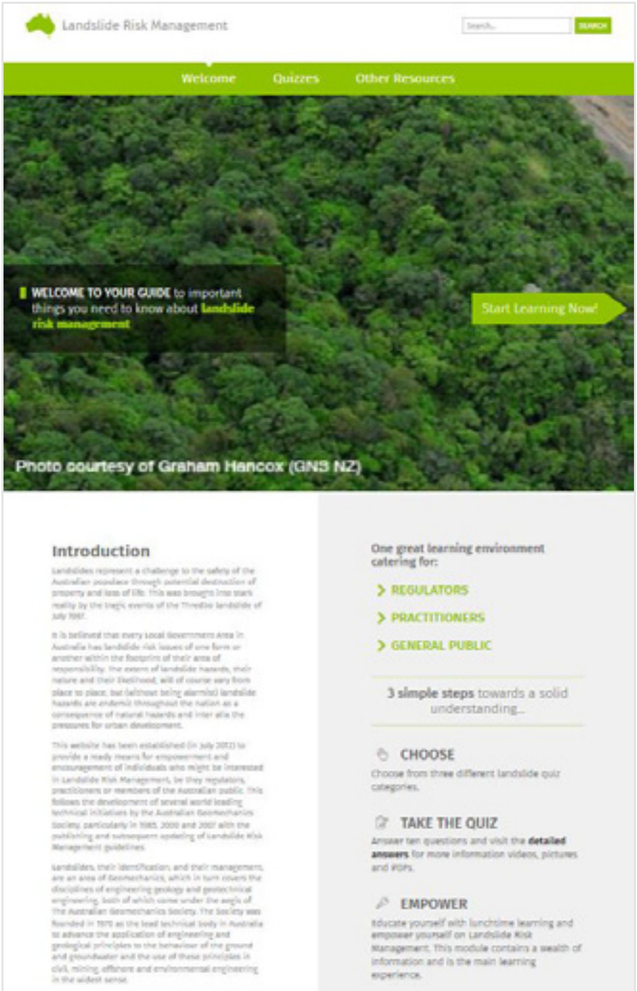
Across the ditch, New Zealand realised they had more Engineering Geologists than Australia and so it was agreed that representation on the International Association for Engineering Geology and the Environment (IAEG) be shared equally between AGS and NZGS.

The AGS website was re-launched with members-only content such as AGS journals, meeting videos, conference papers and other resources.

The efforts of the Landslide Risk Management sub-committee were realised with the launch of the Landslide Risk Management Education Empowerment website. AGS and the Sydney Coastal Councils Group made a submission to the 2013 Resilient Australia Awards. The submission was recognised as being of national significance and was highly commended.

The Hon Michael Keenan, MP, Geoff Withycombe, Andrew Leventhal

The review of Australian Standard AS1726–1993 *Geotechnical Site Investigations* continued with an AGS sub-committee tackling the task with vigour. This was a big relief as the project had the potential to be drawn out. The AGS sub-committee kept the Standards Australia committee focussed and provided excellent representation. AGS had a particularly strong voice on the Standards Australia committee with several AGS friendlies sitting on the committee in other capacities.



Landslide Risk Management website

DARREN PAUL CHAIR 2014-15

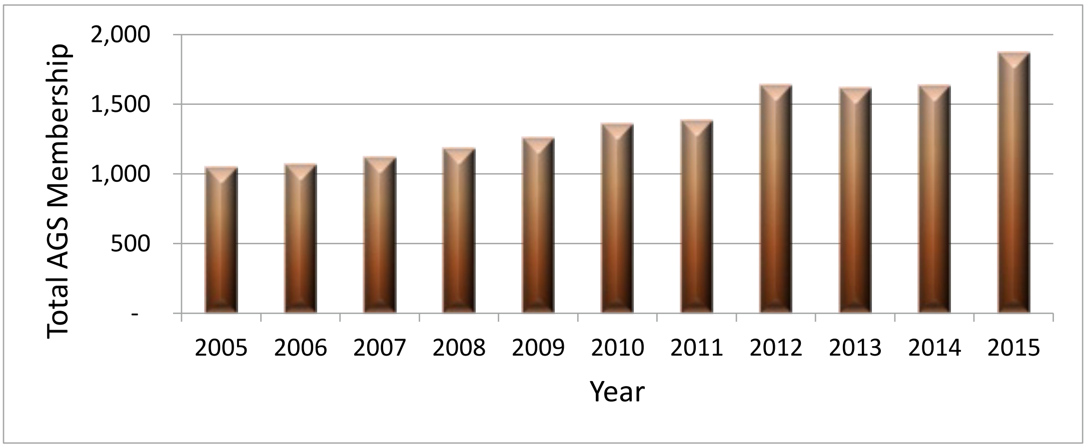
Tweet that.

We need to modernise and stay relevant.

#Australian #Geomechanics

One of our young members, Alistair Schofield receiving the Jack Morgan Award for young geotechnical professionals from Dr Jack Morgan in 2015

It was a tough time in 2014/2015 for geotechnical professionals. The mining industry was going through a downturn, with reduced investment and development. Infrastructure spending was also poor in some states due in part to changes of government. For example, with a government change in Victoria the $22.8b East-West Link Project was cancelled after the contract was awarded and after engineering firms had recruited and prepared to meet the massive workload expected to come with the project.



AGS membership statistics from 2005 to 2015, the 10 year period over which Peter Robinson was secretariat of the AGS

Whilst 2014/2015 was a challenging time for the industry, the AGS continued to flourish and build through this period.

In tough times, it would not be unexpected to see a decline in membership of engineering professional societies. However, through 2014/2015 the AGS grew its membership, from just over 1600 at the start of 2014 to more than 1800 at the end of 2015. In 2013 the average age of our membership was 45, a number we sought to reduce with increased student and young membership, shaving 5 years off the average by the end of 2015.

Engagement with our young members was a key focus of the AGS through 2014 and 2015.

The Jack Morgan award is made by the Victorian Chapter to an outstanding geotechnical practitioner under the age of 35 and comprises a real chrome plated DCP hammer.

The healthy growth in membership was matched by healthy financial growth through this period of about 15%; money that helped the AGS launch and sustain its bid for the 2021 International Conference on Soil Mechanics and Geotechnical Engineering and which was invested back into our members and profession by developing and delivering more professional training than ever before.

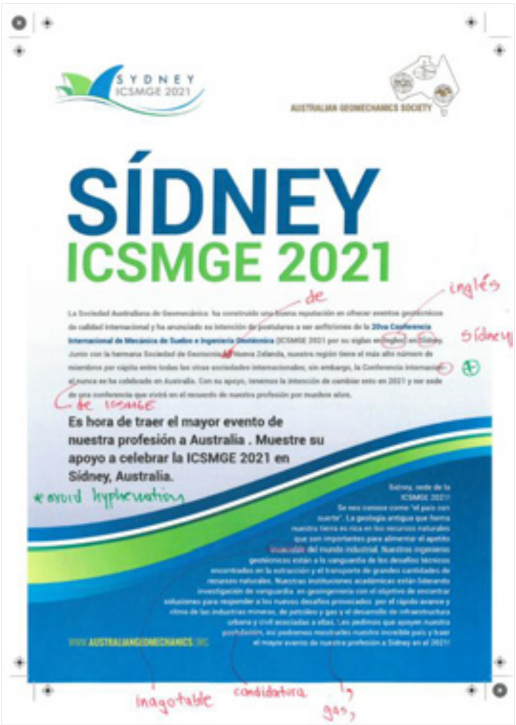
SYDNEY 2021 BID

In November 2014 at the International Conference for Environmental Geotechnics in Melbourne, the AGS launched its bid to host the 2021 ISSMGE congress on soil mechanics and geotechnical engineering.

The bid committee headed by Graham Scholey worked very hard during 2014 and 2015 on a strategy to launch our bid early and promote it as far and wide as we could. The committee went on to attend regional international conferences of the ISSMGE in Buenos Aires, Argentina, Fukuoka, Japan and Edinburgh, Scotland.

Brochures were produced in 8 different languages, videos prepared and willing members promoted our bid at conferences all around the world. The AGS at that time had a very diverse membership and we never had to look far amongst our membership to find willing translators to help promote our bid to all of the ISSMGE member societies.

Of course, we went on to successfully be awarded the 2021 conference thanks to the hard work from our many volunteers in 2014 and 2015.



Our Spanish brochure duly reviewed and edited by Hugo Acosta-Martinez

CONFERENCES

On 10 – 14 November 2014, the International Association of Environmental Geotechnics held its conference in Melbourne. This was a highly successful event, attracting an array of world leading professionals in this specialised field.

The Australia New Zealand Conference on Geomechanics was held in Wellington in February 2015, a conference that lived up to the high standard set by previous ANZ conferences. A lot of innovative work was coming out of New Zealand at the time related to the rebuilding of Christchurch following the devastating 2010 Earthquake. This was a key theme and highlight of the conference.

ISSMGE banner and brochures on display at the XVI European regional Conference on Soil Mechanics and Ground Engineering (left) and the 15th Asian Regional Conference on Soil Mechanics in Fukuoka, Japan (right)

STANDARDS AS1726 REVISION

In 2014 and 2015, our subcommittee for redrafting Australian Standard AS1726 on site investigations worked hard to develop a draft standard and went on to form a standards subcommittee. The standard was released in 2017, however the revision was a good 5 years in the making.

Redrafting the standard was an interesting experience which deeply engaged the profession. This standard is fundamental to almost everything we do as geotechnical engineers, and not surprisingly we had some polarising and strong opinions put forward through the engagement process.

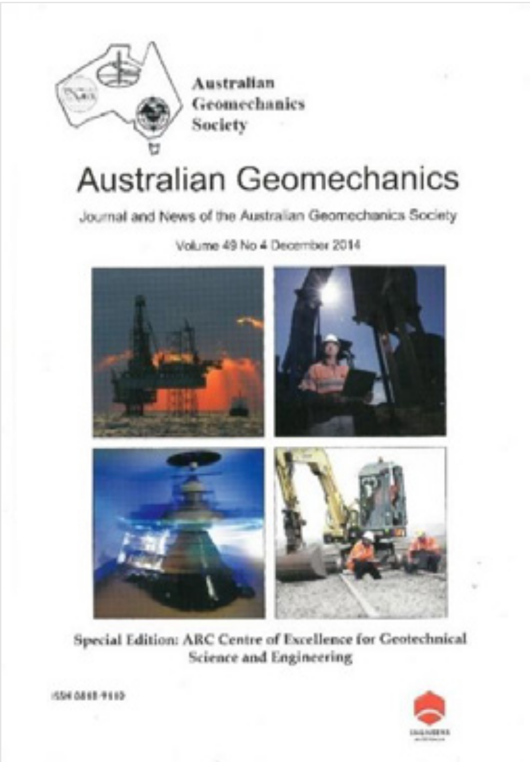
SECRETARIAT

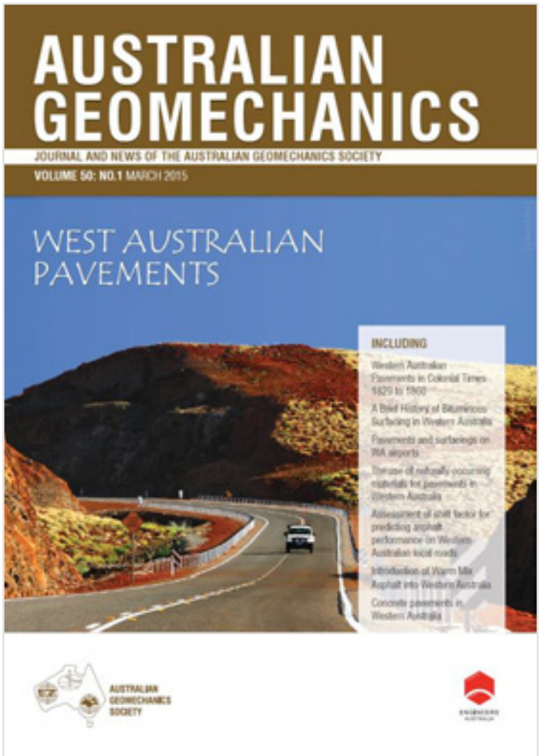
In 2015, Peter Robinson chalked up 10 years as the Secretariat of the AGS. His impact on the society over the 10 years to 2015 was outstanding, taking us from a challenging financial position to one of strength. Peter personally oversaw membership growth and retention, keeping our membership numbers high by hitting up the phones regularly to follow up unpaid memberships. He worked efficiently and tirelessly in the best interests of the AGS.

AUSTRALIAN GEOMECHANICS JOURNAL AND IMAGE

Patrick MacGregor continued his long tenure as editor throughout 2014 and 2015, and was instrumental in producing special editions over this time including Victorian Geotechnics, Offshore Geotechnics, West Australian Pavements and highlights of the 2015 ANZ conference.

In 2014 the AGS started on a major rebranding exercise. The services of a graphic designer, Rebekah Hayne and then Richard Heath were brought in to update the look of our journal and our professional image. As well as updating the look of the journal, all past issues were made available to our members via the members zone of our website. We also updated business cards, merchandise and email signatures in line with our new image.





Final journal edition in the 'old format' (left from December 2014) and new format (right from March 2018)

AGS email footer introduced in 2014

SHALLOW GEOTHERMAL ENERGY IN AUSTRALIA

Following a PhD from the University of Southampton in 1972, Ian Johnston has worked on geotechnical projects in many countries, held senior academic appointments including at Monash University and the University of Melbourne and been active on several professional and governmental boards.

He presented the E.H. Davis Memorial Lecture in 1991, received the John Jaeger Memorial Award in 2012 and was appointed an Officer of the Order of Australia (AO) in 2017.

PROFESSOR IAN JOHNSTON AO

Geothermal energy can have many different forms. It is found in seismic regions (such as in Rotorua in New Zealand) where hot water and steam rise to the surface and can be harnessed for various uses. For non-seismic areas, boreholes can be extended downwards to obtain water at increased temperatures for use in a range of heating applications. If the conditions are appropriate, it is also possible to drill boreholes to several kilometres to extract water hot enough to produce electricity using turbines at the surface.

However, there is another form of geothermal energy which makes use of the ground at normal temperatures. From around 5m below the ground surface to over 100m depth, the ground displays a temperature which is a degree or two above the weighted mean annual air temperature at that particular location. For example, in Melbourne, this is about 18°C and in Brisbane, about 23°C, with temperatures at shallower depths varying according to the season. Shallow geothermal energy (sometimes referred to as direct geothermal or geoexchange) uses this region as a heat source in winter and a heat sink in summer for heating and cooling buildings.

Water is circulated through a ground heat exchanger (or GHE, which comprises pipes built into building foundations, or in specifically drilled boreholes or trenches) and back to the surface. In heating mode, heat contained in the circulating water is extracted by a ground source heat pump (GSHP) and used to heat the building. The cooled fluid is reinjected into the ground loops to heat up again to complete the cycle. In cooling mode, the system is reversed with heat taken out of the building transferred to the water which is injected underground to dump the extra heat to the ground. The cooled water then returns to the heat pump to receive more heat from the building.

Figure 1 shows a schematic view (not to scale) of a reversible system. For each kilowatt-hour of electrical energy put into a shallow geothermal system, about 4 kilowatt-hours of energy are developed for heating and cooling. This means that outside the capital costs of the installation, about 75% of the energy is free. Furthermore, where electrical energy is generated with coal, replacing 75% of the energy used with a clean renewable energy source, the greenhouse gas emissions are reduced by as much as about 75%. While the capital costs of installation of a system are still a little high in Australia, with industry becoming better geared to needs, and with better systems of design and installation, costs should fall significantly over the next few years. This, combined with the likely major increase in costs of conventionally derived energy, will mean that capital costs can be recovered in a few years.

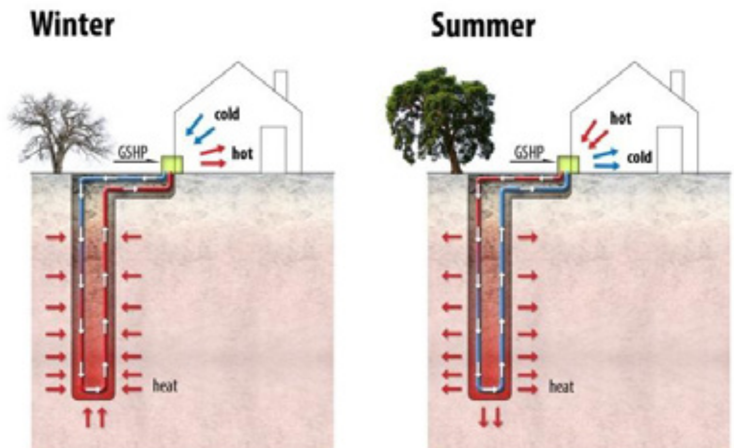


Figure 1: Shallow geothermal heating and cooling system

Figure 2: Horizontal loop system at Main Ridge before backfilling

Geothermal heating and cooling systems have been commonly used for around 20 years with several million individual systems installed in Northern Europe, North America, Korea and China, with the rate of installation increasing rapidly.

Originally, design and installation was undertaken by heating and air-conditioning engineers but over recent years, geotechnical engineers have become increasingly involved, partly because of the need to understand, and take into account, the complexities of the ground, and partly because of the increased use of energy geostructures (using ground structural elements such as piles, retaining walls and tunnels as GHEs).

While the heating and cooling demand of a building and the selection of the GSHP are critical issues for any application, the design and construction of the GHEs are the principal interest of the geotechnical engineer. There are several approaches to achieve this ranging from relatively crude rule of thumb methods, through analytical and semi-empirical methods such as those recommended by the International Ground Source Heat Pump Association (IGSHPA) and the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE), for borehole and trench GHEs, to more sophisticated software for energy piles and other geostructures.

There have been comparatively few geothermal installations in Australia to date for reasons that are probably linked to the relatively moderate heating and cooling demands in many population centres, the lack of any government incentives in the form of subsidies (which exist in most other countries where geothermal has seen high adoption rates), the relatively high installation costs in Australia, and low public awareness of the technology. Despite this, there are a small number of companies in Australia which specialize in borehole and/or trench GHEs, and even fewer commercial organisations which can design and construct energy piles and other geostructures.

There has, however, been a significant amount of research and development in Australia over recent years related to the design and construction of GHEs in general and the geotechnical factors which control their operation, particularly relating to Australian conditions. Most of this work has been at the University of Melbourne and at Monash University, although there is a growing interest in this technology at other institutions.

Research into shallow geothermal systems at the University of Melbourne commenced soon after Ian Johnston took up the Chair of Geotechnical Engineering in 2008 and Guillermo Narsilio's appointment to the academic staff. Despite the importance of GHEs in these systems, there had been little detailed study anywhere of heat transfer in the ground and the many factors which control design and construction.To reduce the conservatism inherent in design procedures, the university decided to undertake a series of field tests on systems involving borehole and trench GHEs and energy piles in which factors such as GHE dimensions and depth, pipe size, spacing and relative location, grout and ground thermal conductivity, heating and cooling demand and water flow rates were considered. All of these systems included extensive instrumentation which allowed detailed analyses of performance. Stuart Colls (PhD, 2013) commenced the development of a field installation of several 30m deep energy pile and borehole GHEs.

Following this initial fieldwork, and with the considerable financial support of the Victorian Government (and extensive practical support from Gerry Noonan of Geotechnical Engineering), several projects were initiated to improve the understanding of shallow geothermal systems operating under Australian conditions. Amir Kivi (PhD, 2015) installed a horizontal geothermal loop system at Main Ridge some 80km south of Melbourne (Figure 2).

Another project was the design, installation, detailed monitoring and analysis of the system installed at the Elizabeth Blackburn School of Sciences (EBSS) (Figure 3).

Figure 3: The Elizabeth Blackburn School of Sciences

This is a 120kW system comprising 28 individual boreholes, each 50m deep, and each with a double loop configuration of grouted HDPE pipes (Figure 4). Olga Mikhaylova (PhD, 2017) took on the considerable responsibility of supervising the installation and despite many problems arising during construction, successfully completed and commissioned the system.

Figure 4: Double loop prior to grouting at EBSS

Figure 5: Heat pumps and other surface components at EBSS

She also made some important contributions relating to system performance, assessment of uncertainties, hybrid systems and analytical models. Figure 5 shows the four 30kW heat pumps and other surface components at EBSS.

A third major project, funded by the Victorian Government, involved the installation of monitored geothermal systems in about 18 residential properties throughout Victoria. Riyan Aditya (currently enrolled for a PhD) designed and installed the systems and instrumentation, and then collected the performance data via the internet from around the state.

It was recognised early on that existing numerical models were limited in their ability to account for the effects of a number of critical parameters in geothermal design. This led to the development of a comprehensive general numerical model for shallow geothermal systems using COMSOL Multiphysics. Asal Bidarmaghz (PhD, 2014) worked on this model to predict the complex short and long term heat transfer process in GHEs and in the ground for a wide range of system configurations. Currently, PhD students Qi Lu, Nick Makasis, Linden Jensen-Page, Riyan Aditya and Yu Zhou are looking into a variety of other issues with GHEs including the assessment and comparison of different design approaches, financial assessments against other forms of heating and cooling, district and hybrid systems, extension of the modelling capability of numerical systems and the thermal characterization of the ground particularly using thermal response tests. This work involves geothermal systems installed at a number of projects including parts of the Melbourne Metro Project and the Melbourne Connect building (Figure 6) in Parkville as well as at several other commercial and residential projects.

Monash University has also been involved with shallow geothermal energy for several years under the general direction of Malek Bouazza.

Figure 6: HDPE geothermal pipes fixed in pile cages for the Melbourne Connect building

The primary interest of this group has been related to the effects of thermal loading on the structural and geotechnical performance of energy piles. Tests have been conducted on full-scale instrumented bored piles installed both with and without vertical loading; the former as a group of piles installed in dense saturated sand supporting a six-floor building at the Clayton Campus. The instrumentation included Osterberg Cells, vibrating wire strain gauges and thermocouples and the piles were subjected to different temperature cycles representing real-life operating conditions of the ground source heat pump. The results showed that, for the conditions investigated, there was no observed degradation in the shaft capacity of the piles. Further, although the radial thermal stresses induced in the loaded piles were considerably lower than the axial thermal stresses, these thermal stresses did not lead to significant thermally induced deformations of the piles. This research was carried out with several other Monash personnel including Bill Wang (MEngSc, 2017), Rao Singh (Research Fellow, 2009-2015), Gary Yu (MEngSc, 2015), Bing Fang (MEngSc, 2016), Mohammed Faizal (PhD, 2018), Aria Moradshahi (PhD, current), Hassam Ayaz (MEngSc, current) and input from Chris Haberfield of Golder Associates, Serhat Baycan of Vibropile and Yale Carden of GeoExchange.

Figure 7 shows one of the instrumented reinforcing cages being installed at Monash University.

A recent project, supported by Lend Lease, involves the installation of an instrumented group of CFA piles, pile cap and connecting slab with the aim of investigating the thermo-mechanical interactions of all these components.

Another useful Monash contribution to geothermal design processes in Melbourne was the work of David Barry-Macaulay (MEngSc, 2013) who measured the thermal conductivity of various soils and rocks commonly encountered in Melbourne.

While Melbourne has a relatively balanced heating and cooling demand pattern, the more northern states are usually characterized by a cooling dominated pattern.

As much of the GHE design and construction techniques have been developed for regions more typical of the balanced pattern, a team from the University of Queensland led by Kamel Hooman, has commissioned a fully instrumented GSHP experimental facility on their Gatton Campus. The purpose of this is not only a public demonstration of the technology but also a platform for systematic studies of GSHP technology operating in subtropical regions. The installation was fully commissioned in early 2016.

The extensively instrumented installation consists of two independent systems; one a refrigerant direct expansion (DX) system and the other a more conventional HDPE water loop system. Each system has 20kW capacity. There are six operating boreholes arranged on an 8m grid. Apart from the operating boreholes, each loop system has three monitoring wells to measure the ground temperature with depth over time. In addition, there is a 100m deep background monitoring borehole approximately 50m away from its nearest operating borehole. This well provides reference measurements on the ground conditions of this area during the long-term operation of GSHP system. Figure 8 shows the above ground components of the installation. Kamel, along with colleagues Yuanshen Lu, Aleks Atrens, and Hugh Russell will be presenting data on the performance of the facility in the near future.

Another project recently commenced at the University of Queensland under the direction of David Williams and with research student Scott Lines is an investigation of the long-term effects of ground temperature imbalance from the use of energy foundations and an examination of possible alternatives to offset any negative effects. This particular project also included a number of thermal response tests and thermal recovery tests conducted on an instrumented energy pile installed in the Brisbane River sediments.

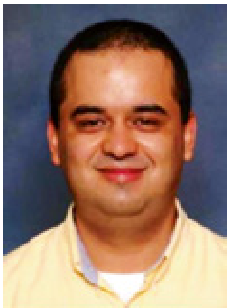
The outcome of this research and development into shallow geothermal energy at several Australian institutions should lead to a much greater understanding of the capacity and performance of shallow geothermal systems and provide the basis for less empirical design processes, reduced conservatism and more cost effective designs, not just for Australian conditions but for conditions encountered internationally. With the growing recognition that we must act on climate change, it is likely that shallow geothermal energy will be added to the mix of other sustainable sources of energy to help us get there.

Figure 7: Instrumented energy pile cage for Monash test facility

Figure 8: Above ground components of Gatton test

Figure 9: Energy pile for Brisbane River sediments

DR HUGO E. ACOSTA-MARTINEZ CHAIR 2016-17



AGS is a great organisation thanks to the continued and considerable voluntary effort and support of its members. This book represents another example of that commitment.

It was a real privilege and I felt honoured and humbled for the opportunity to lead the AGS during 2016-17. Being the first Chair from a non-English speaking country speaks volumes about the diversity and inclusiveness of the AGS and the opportunities offered by this great country.

When I was a Civil Engineering student in Colombia, the course on Foundation Engineering contained multiple references to the work in geomechanics developed in Australia. The research papers coming from the University of Sydney and the University of Western Australia (UWA) on piled and piled-raft foundations were of interest for the design of infrastructure foundations in the very soft and highly compressible deep lacustrine clay deposit in Bogota. That was probably my first contact with Australian geomechanics. My first direct "contact" with the AGS occurred a few years later when I filled out an order form to get a CD copy of the proceedings from GeoEng2000 for the office. We received it and grew increasingly fascinated by all the work done in Australia and captured in this book. I remember discussing how such a great event and line up of speakers could be put together, a practice that has continued.

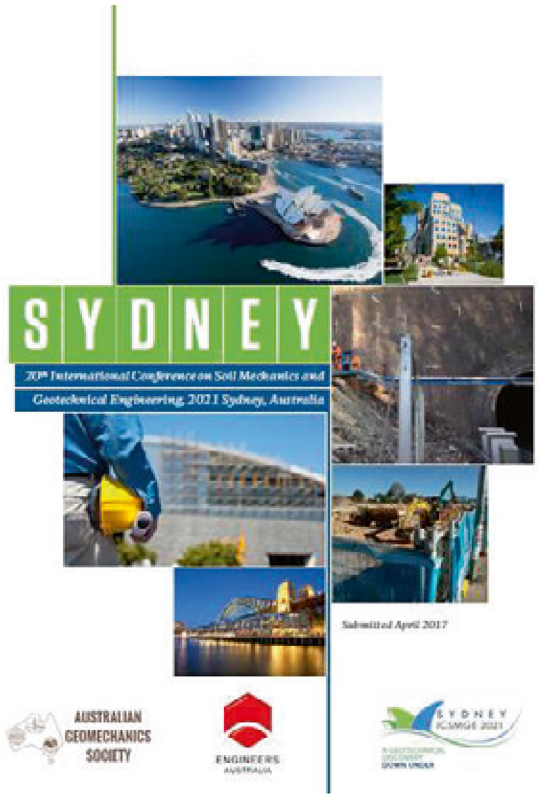
I moved to Australia in 2005 to carry out PhD studies at UWA. My first indirect involvement with the local WA Chapter of AGS was by forwarding the announcement of local technical presentations (which I received from Prof Barry Lehane) to the graduate students mailing list. Towards the end of my studies, Barry invited me to be part of the local committee, which I happily accepted. I had some experience in that type of activity from work with the Colombian Geotechnical Society, but the membership alone for the WA Chapter, and the number of activities carried out regularly were a different order of magnitude.

It all happened very quickly. I went from being a regular committee member to treasurer, then secretary and finally chapter chair. The latter provided me with the opportunity to join the national committee, of which I was a member until 2019.

I had some very big shoes to fill as National Chair after Darren's period. His guidance and support, well beyond his time in the National Committee, were invaluable and made the task much easier. Of course, the support from Peter Robinson in the Secretariat was vital. His professionalism and dedication to the AGS are reflected in the extraordinary current position of the AGS as a learned society.

The start of my term as Chair continued to be a challenging and difficult time for geomechanics professionals, particularly in Western Australia where I was based. I relocated to Adelaide in June 2016 and spent almost a year there before returning to Perth. The period in Adelaide provided me with invaluable time to work on AGS initiatives.

The most memorable moment of that period was probably when the AGS bid to host ICSMGE-2021 in Sydney was unanimously approved by the ISSMGE Council during the meeting in Seoul in September 2017. I had the opportunity to represent the AGS in that meeting and was accompanied by Graham Scholey and Prof John Carter.



Cover page of AGS proposal to host ICSMGE-2021

We were seated in the first row and I can clearly remember how moved I felt watching the promotional video (https://youtu.be/Pp6-ud-3ypE) projected on the big screen. The best part followed soon after, when everyone voted in favour of the Australian bid. A lot of people were involved in the process, but I must recognise the commitment and determination of Graham Scholey in bringing that event to Australia.

All smiles, happiness and relief with Graham Scholey in Seoul, the day after the AGS proposal to host ICSMGE-2021 in Sydney was approved

During the 2016-17 period the membership continued to grow, and improvements were made to the website. A trial of a LinkedIn page was started by the Sydney Chapter to increase our presence in the social media space, in addition to the Twitter account.

In relation to CPD offerings, the first AGS Workshop on Unsaturated Soil Mechanics for Practicing Engineers was fully subscribed and held in Sydney in 2016. This was also the year that the first series of Geological Mapping courses began. During 2016-17 a number of local eminent speakers presented to our members in Australia special lectures corresponding to National AGS awards, including Prof Daichao Sheng and Dr Richard Kelly. Dr Suzanne Lacasse (NGI) and Prof Richard Jardine (Imperial College London) were also invited during this period. The distinguished speakers program continues to be a great initiative to keep our membership connected to state of the art international research and practice in geomechanics.

Following several years of work on the revision of AS1726 Geotechnical Site Investigations, the current version was finally published by Standards Australia in 2017. In the process I remember putting together in a day or two a roadshow to discuss the draft released for public comment, as well as compiling comments from discussions of all those sessions and others received via email. Some of issues raised in the feedback were contradictory but sending all that back to the Committee reflected the transparency of the process.

The Fifth International Conference on Geotechnical and Geophysical Site Characterisation (ISC'5) was hosted by the AGS on behalf of technical committee TC102 of the ISSMGE. It was a very successful conference and two volumes of proceedings were made freely available at the AGS and ISSMGE Online Library platforms in support of the Open Access initiative. The December 2016 issue of *Australian Geomechanics* included the papers from the ISC'5 keynote lectures. More than 120 additional copies of that issue were printed and mailed to key members of TC102, the ISSMGE Board and all Chairs from ISSMGE TCs. We wanted to highlight the capacity of the AGS to organise great events.

In relation to the journal, Patrick McGregor decided in late 2016 to retire from the position of Editor of *Australian Geomechanics* after 16 years of dedicated service to the journal and the AGS National Committee. A succession plan was in place and the June 2017 issue was the first one edited by Tanya Kouzmin. During this period there was also an effort to add more content to the news section preceding the technical papers, including the initiative to publish PhD theses abstracts from research in Australia or by Australians at overseas universities.

In relation to representation in the international societies, during this time a memorandum of understanding was signed between AGS and NZGS regarding the rotation sequence for the Vice-President roles for the ISSMGE and IAEG, and a 1:1 rotation was agreed upon. In relation to the ISRM, this period saw an unfortunate and regrettable event by which the ISRM Board decided to declare invalid the nomination of Prof Jian Zhao for ISRM President on grounds that were strongly challenged by the AGS. Further details are provided by Stephen Fityus.

My last AGM and National Committee meeting as Chair of the AGS was held in Hobart on 2017 and saw the election of Dr Nina Levy as Treasurer of the AGS, marking the pathway for the first female Chair of the AGS. A fitting milestone for the 50th anniversary celebrated in this book.

I cannot emphasise enough how great a learned society the AGS is, thanks to the continued and considerable voluntary effort and support of its members. This book represents another example of that commitment.

It was a real privilege, and I felt honoured and humbled for the opportunity to lead the AGS during 2016-17. Being the first Chair from a non-English speaking country speaks volumes about the diversity and inclusiveness of the AGS and the opportunities offered by this great country.

PROFESSOR STEPHEN FITYUS CHAIR 2018-19

What differentiates geo engineers from others is the challenge of the natural world; it all begins with fieldwork.

The AGS that I served in its 48th and 49th years was a very different organisation to the one that the first AGS chairs served. With a membership teetering at just below 2000, it was a much busier and more businesslike organisation that it was in its earlier days. At 30 June 2018, the Australian Geomechanics Society (AGS) had a national membership of 1,843 which included 242 student members and 123 corporate members. This number had increased to more than 1,950 members by June 2019, and the Society was variously active across all seven of its chapters. Notably, in 2018, a small group of NSW chapter members based in Canberra expressed an interest in hosting some events in Canberra. The Sydney chapter undertook to liaise with this group and to assist them to host a small number of events in Canberra that were very well attended.

2018 saw unprecedented offerings to our members through specialist conferences and courses. State chapters in NSW, QLD, SA and VIC all held annual symposia in late 2018. The agenda for 2018 included 4 Soil and Rock Logging courses (including a Soil and Rock Logging course held in Darwin as a service to our more remote members), 8 Geotechnical Mapping courses, 2 GIS for Geotechs courses and 2 Unsaturated Soils courses. 2019 saw a further 4 Soil and Rock Logging courses, an Applied Landslide Risk Assessment course and an Engineering Geology course. Altogether, in 2018 alone this represented around 380 professional development opportunities for AGS members, in addition to the full programs of technical seminars offered by the local chapters.

The AGS continued to maintain strong relationships with its affiliated international societies, the ISSMGE, IAEG and ISRM. A highlight of our international involvements was Mark Eggers (AGS) nominating with Ann Williams (NZGS) for the role of joint presidents of the IAEG. Disappointingly, their bid for presidency was not successful, but they did give the winner an admirable challenge. However, 2017 also saw a "difference of opinion" arise between the AGS executive and the ISRM Board. In a disputed interpretation of (then) ISRM by-law 2.4, AGS was reprimanded in 2017 for announcing we had nominated Professor Zhao for the ISRM presidency, before the ISRM had formally announced it.

After some indignant exchanges of communications between AGS and ISRM (on both sides), they demanded we tender a formal apology for our indiscretion, and we politely refused. They ruled our nomination invalid, and that's pretty much where the matter ended. We did go on to seek to have the disputed by-law clarified at the next council meeting, but in the end, the only point we made was a point of principle.

Early in 2018, Emeritus Professor John Carter assumed the role of chairman for the 20th International Conference in Soil Mechanics and Geotechnical Engineering in Sydney in 2021 and convened an organising committee. In November 2018, the very successful 12th Young Geotechnical Professionals conference was held in Hobart, and a great time was had by all. Following this, in April 2019, the 13th ANZ conference was held in Perth. An incredibly successful event, the good planning and hard work of Michael Smith, Hugo Acosta Martinez and Barry Lehane managed to attract 465 members and non-members alike, to exceed all expectations.

Notably, the winner of the 2017 AGS Practitioner Award, Rob Day, went on to win the Sir John Holland Civil Engineer of the Year Award in 2018.

Perhaps my biggest challenge as chair of the AGS in this period was dealing with a series of 3 papers submitted to Australian Geomechanics on the Lane Cove Tunnel collapse. These papers boldly attempted to analyse both the technical and contractual factors which led to the collapse, and to recount and critique the legal aftermath of the event. Whilst the papers were potentially of great interest and value to our membership, in that they dared to teach us something from one of our (relatively few) failures, they were unavoidably fraught with contention and inevitably, insurmountable issues were identified which caused the AGS executive to have them retracted from the journal. We learned much from that episode, in which we spent 5 months teasing apart the papers and the different issues which arose in relation to them.

A notable observation of the times can be made in relation to the issues that the AGS was addressing. A particular set of issues which had come of age at this time related to the management of geotechnical data, and these became items of consideration for the National Committee.

One of these was in regards to standardisation in geotechnical logs. On the back of the latest revision to AS1726 -2017 (Geotechnical Site Investigations), an initiative was proposed to see the Australian industry adopt a common geotechnical data presentation format.

At the time of writing this account, members were being surveyed to gauge their disposition toward adopting a common data format, should one be developed. At the same time, a working party had begun to develop a format which might serve that purpose.

Another data-related issue which had come to the fore related to open access to past geotechnical data. From time to time throughout my career, it had been suggested by various colleagues that there should be a repository of all historical geotechnical data, which could be publicly accessed to serve the greater good. In the early part of my career, such suggestions were invariably dismissed on the grounds that in any given area, the IP of past geotechnical data was of great commercial value, giving individuals and firms a local market advantage. However, as the years had passed, I had noted that the number of suggestions had increased, and the number of dismissals had declined. With the occurrence of the Christchurch earthquake, after which the NZ government made participation in a public repository of geotechnical data a mandatory part of participation in the rebuilding process, accounts began to emerge across the profession as to what a wonderful initiative this had become. By 2018, an ad-hoc straw poll of a random bunch of geo practitioners at a congress, found that there was unanimous agreement that such a data repository was a good idea and that it should be explored by the AGS. This issue had long been a pet interest of Tim Thompson of the Qld Chapter, who had played a role in seeing a public database established for all new geotechnical data acquired for Queensland Main Roads and Brisbane Council. Consequently, the National Committee gave Tim authority to formally gauge the support for a national geotechnical data repository, across the full AGS membership. At the time of writing this account, no decisions regarding the future of such a repository had been reached.

My time as AGS chair came very late in our first fifty years, so much so that it was indeed during this period that the prospect of a 50th anniversary was identified. Such anniversaries are always challenging events to celebrate, and it fell to the National Committee to deliberate over whether we would mark the occasion in some special way; and if so, how and when. A few years earlier, the IAEG had marked its 50th anniversary with a glossy colour commemorative book, which profiled all of its grand old presidents and other IAEG luminaries. Whilst it served as an impressive coffee table book, it didn't seem to capture well the identity of the Association and the achievements of its broader membership. The National Committee briefly considered its own fancy book researched and written by a historian, but opted instead to produce a simpler "grass roots" commemorative book, in the format of Australian Geomechanics, but comprising stories of the AGS told by its past chairs and luminaries; not stories told about them.

We also considered that there should be something else to mark the occasion, and it was observed that whilst the AGS had always had provision in its constitution to bestow honorary life membership to its most deserving members, this had never actually been exercised. So it seems most appropriate to mark the occasion of our 50th anniversary by conferring our first ever round of honorary life memberships.

As the last of the AGS chairs before our 50th anniversary, it is appropriate that I look at where we are now and how we are posed to embrace the next 50 years. The AGS is certainly bigger and more active than it has ever been, and it seems that both members and non-members alike see great value in availing themselves of the CPD opportunities we offer. In that sense we are in a great place to move forward and to grow as a society. In the 30 years since I first became engaged with the Society, many things have changed greatly, and probably none more so than the way we communicate with our members. 30 years ago (and before), the AGS was a smaller and more closely-knit community, and communications were adequately achieved through landline telephone and paper mail transactions. The advent of email made bulk instantaneous communication possible, and the establishment of a maintained website meant that our membership could seek information about the Society's activities whenever they wished. This has more recently been enhanced through our use of LinkedIn and Twitter.

But for all of this enhanced communication within the Society, it seems that the level of engagement and activity has not really changed, and in some respects it may even be a little diminished. It seems to me that, in the greater societal sense, the enhanced connectivity has combined with other technological and social changes to make everyone "time poor". That doesn't mean that our members are busier or working harder than they did 50 years ago, but I am observing that we are now finding it harder than ever before to engage with the society at a face-to-face level, and to follow up on our commitments as volunteers. We are as driven and as passionate about our profession as ever we were, but the world in which we operate has changed; everyday life is more complex and our priorities are now simply more divided. This, coupled with online platforms to facilitate meetings without the need for physical presence, seems to be making it increasingly difficult for members to get together and commune as a professional society. If I were to speculate as to the things which threaten the AGS as a society in the next 50 years, it would be the ongoing social and professional changes which ironically, whist giving us unprecedented potential for connectivity, threaten to make us more isolated and less available. I hope that we do not lose our passion to make that space in our busy lives to put an afternoon or evening aside to get to that technical talk or committee meeting, and perhaps, join the speaker and the committee for dinner afterwards.

In concluding this small recollection, I would like to personally recognise the many fellow geoprofessionals, who throughout my involvement with AGS, have supported me as mentors, teachers, peers, colleagues and friends.

I would especially like to thank Hugo who preceded me as chair, for the excellent support and wisdom he has shared with me in his role as past chair, which has ensured a smooth and sound transition at the head of the AGS. I would also like to especially acknowledge Peter Robinson for going above and beyond in his role as secretariat, and for being the heart and soul of the AGS for the best part of 15 years. I have absolutely no doubt that we would not be in the excellent shape we are now if it were not for Peter's hard work, insight and diligence. Thank you Peter.

Here's to the next 50 years

Vignette from *Australian Geomechanics* March 2019

Australian Geomechanics Society Continuing Professional Development

Geology for Engineers and Engineering Geology

The Australian Geomechanics Society (AGS) delivers a range of Continuing Professional Development (CPD) courses to enhance the career development of the society's members in the discipline of Geology and Engineering Geology. In November 2018 the Geology for Engineers course was delivered for the 8th time, and each course has been sold out, an impressive feat. In November 2019, the newer Engineering Geology Course will be delivered for the 5th time. Both courses currently accept 24 registrations and are now scheduled to run during early November in consecutive years.

Dr Fred Baynes, Dr Phil Flentje, Mark Eggers and Anthony Bowden presented the course and this time they were joined by Ian Shipway. This same 5 member team will also deliver the Engineering Geology course later in 2019.

The AGS Geology for Engineers course concentrates on teaching engineering geological field observation and data collection skills that can be used to solve real engineering problems. Based at the University of Adelaide and at sites around the city and the nearby south coast of the Fleurieu Peninsula, the presenters used a range of supervised field exercises, which are related to dams, coastal erosion, slope stability and caverns to demonstrate and develop useful skills. A teacher to student ratio of 1:6 is maintained throughout.

Participants travelled to Adelaide from all over Australia for this weeklong residential course. They came with a broad range of professional backgrounds, knowledge and experience, but all shared a common interest in developing their understanding of geological materials and processes to advance their careers in ground engineering. Participants commented on how much they had benefited from the daily one-on-one feedback sessions and the personalized support that they received from presenters during the exercises. Despite a couple of days of rather challenging weather, everyone had a great time.

In November 2019, as mentioned above the AGS will run, for the 5th time, the successful Engineering Geology course based out of the University of Wollongong and sites throughout the Illawarra and south coast of NSW. This is a sister course to Geology for Engineers and is aimed at developing the skills of geologist and geotechnical engineers who already have a sound understanding of geological principals. We are currently looking to build our next team of 24 engineering geologists to join us in November 2019 in Wollongong.

Field sketching the distant angular unconformity exposed at Blanche Point.

Field mapping at Port Willunga beach

2016 group photo at the Port Elliott site

2010-2019

FIVE AND A HALF DECADES OF PILING

John Wagstaff is currently the Chairman of Wagstaff Piling Pty Ltd and associated companies.

He commenced a cadetship in 1965 with Frankipile and graduated from R.M.I.T with a Diploma in Civil Engineering in 1969. John worked with Frankipile throughout Australia, Fiji, UK, Belgium and Indonesia for 16 years.

He established Wagstaff Piling in 1980 and has grown the company over the past 40 years.

JOHN WAGSTAFF

This article is about the engineers and projects that have influenced my life and have helped to educate me as a geotechnical engineer, manager and owner of a foundation engineering company over the past 55 years. I am still learning.

A stroke of luck introduced me into engineering.

During the Second World War my father was wounded at a battle against General Rommel at Tobruk and was evacuated to the military hospital in Cairo. In hospital, my father became very good friends with a Welsh nurse, Esther Jones. After the war my father kept in touch with Esther who was now married to a British Civil Engineer, Peter Mayhew and had two children. Life was very tough in Britain after the war with rationing. Peter and Esther decided to immigrate to Australia in the early nineteen fifties.

I remember collecting them from Princes Pier in Melbourne with hundreds of streamers welcoming the ship and its passengers. My father had rented a house for the Mayhew family at Carrum. There was a gate at the bottom of the garden straight onto the beautiful sandy beach. The Mayhew family thought they had arrived in paradise.

The Mayhews disappeared from our lives as Peter got a job in the Latrobe Valley on the building of the Morwell Power Station; then went to Cooma for the building of the Snowy Mountain River scheme; then to Sydney working for the Letourneau Westinghouse earth moving equipment.

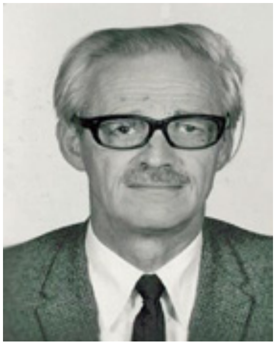
In 1964 Peter returned to Melbourne to a picnic lunch at Point Leo to watch me swim in a surf carnival. In 1964 I was State Champion for the 200m and 400 metre medley, also a surf life saver and finishing year 12 at Melbourne Boys High School. During the picnic Peter Mayhew asked what I intended to study after matriculation; I replied "I didn't really know". I had applied for medicine and science courses at University but it depended on my results. Peter asked "had I ever thought of becoming an engineer?" to which I replied "what do engineers do?" He explained what engineers do and suggested I visit a couple of sites, one of them being the installation of piles for the new railway bridge at Mordialloc. I was immediately impressed and thought this is the life for me.

Mordialloc Bridge

Peter also advised me that Frankipile were advertising for cadet engineers and that if interested I should apply. I did apply and was selected for the cadetship.

So began my engineering journey in January 1965. I enrolled at R.M.I.T as Melbourne and Monash Universities had no part time courses. A cadetship is a great way to enter engineering as you can really learn and apply this to do your daily job better.

For five years my routine was work from 7.30am to 5.00pm, attend lectures from 5.30pm to 9.30pm and then study and assignments from 10.30pm to 12.00am. Most years I also had to attend either some morning or afternoon lectures. For example surveying for 4 to 5 hours around Studley Park took up a whole afternoon.



Peter Mayhew

My boss Peter Mayhew was a hard task master and believed if you were going to instruct employees on what to do, you needed to know how to do it yourself.

I therefore had to spend a day on one of our piling sites each week learning to mix concrete (all concrete was site mixed in the 1960's), wheel a full wheelbarrow of concrete across a rough site, tie reinforcing steel and hand mine with a jack hammer down a pile shaft.

In the early sixties the drilling machines were of limited capacity and could only drill to, and into weathered rock. A-frames were then set up over the drilled holes and hand mining techniques were used to enlarge the base into an under reamed bell. Air winches were used to lower you, your jackhammer and shovel in a bucket, to the bottom of the hole. One worked with a 2 man mining crew, one miner down the hole and one at the top. Usually 2 hour shifts, 2 hours down the hole and 2 hours on the top emptying the buckets of the hand mined rock. It was tough work and there was a lot to learn on how and where to place your jackhammer to fracture the rock into larger pieces- a real art form and skill. Some notable projects I learnt to hand mine on in Melbourne were AMP Headquarters and the Stock Exchange, both in Collins St.

Me learning geology

Next lesson was to learn how to make a good Franki enlarged base pile. This is also a specific art form and involves climbing up the steel ladder built into the piling leader with one leg hooked over one of the runners so you don't fall off. It was not much fun hanging on a ladder 15 metres in the air, in the middle of the winter in Melbourne. Today, with Workplace, Health and Safety rules, climbing a ladder and clinging on with one leg holding you on whilst both arms were busy doing other tasks would be taboo.

During these five years I also had lots of interaction with Cyril Sexton, the "Old Man" as he was known, who was the Managing Director; Geoffrey Sexton the General Manager; John Sexton the Assistant General Manager and Don Douglas who was the Managing Director of Ground Test division of Frankipile. All of these gents had a major influence in my training, especially when I was sent to Sydney headquarters during university breaks.

I made some amusing mistakes during the cadet engineering training years. Don Douglas requested that I go out to Doncaster to set out the bore hole locations for the proposed Doncaster Shopping Centre. As I recall this was Westfield's first major Shopping Centre in Victoria. The site was very hilly +/- 100metres of old farming country in 1968. Don provided a sketch plan of where the bore hole locations were, my job was to set them out running a traverse and provide a reduced level at each bore location due to the hilly terrain. This exercise tested my surveying skills to the limit. Armed with an unskilled labourer as chainman, a theodolite and dumpy level I approached my task with gusto.

Unfortunately my traverse did not quite close; I was a few metres out by the time I got around the very large site. I was very pleased with myself all the same, wading through the long grass, around trees and up and down hills. Don Douglas was far from impressed and tore strips off me for not having completed my traverse to the exact mm.

On another occasion I encountered the wrath of Cyril Sexton, the "Old Man". Frankipile had won the contract to install the foundations for the Westgate Bridge in Melbourne.

Westgate Bridge

I was allocated the task of organising the installation of the test piles, which consisted of driving pre-stressed piles 550mm octagonal, 40 metres deep and 1.5m diameter permanent steel casings driven to rock and the sockets chopped and cored into the underlying bedrock. These caissons were then reinforced and concreted under water. All these piles were then static test loaded with massive steel beams and 100's of tonnes of concrete blocks. All this went very well and Cyril was pleased with my work. The next task was to install a large soldier pile retaining wall to allow tip trucks to reverse up and dump rock into some specially made bins. The rock was required to construct thousands of stone columns through an old rubbish dump to provide a stabilised soil on which to build the approach embankment of the Westgate Bridge on the Port Melbourne side.

The "Old Man" was a brilliant engineer both structural and geotechnical. As the retaining wall was a temporary structure he asked me to source second hand steel beams for the soldier piles.

Detailed sizes for these steel columns were provided by him for me to source. I had great difficulty finding the exact sizes of steel columns specified but managed to source similar but slightly smaller columns. We successfully constructed the retaining wall and Cyril arrived on site to inspect the completed retaining wall.

Cyril was always dressed like an English gentleman in a suit, tie and a hat. He inspected my work and his face went red, his lips trembled and his hat nearly fell off his head and I was called an incompetent fool for not using the correct size steel columns. He then spent about 20 minutes striding around and calculating in his head the strength of the beams I had installed with me following. Finally he calculated that they were overstressed but would carry the loads without failing and proceeded to lecture me that in future I was to do the calculations myself to ensure they wouldn't fail. I think I came close to being sacked that day.

In 1969 I managed to pass my final exams and graduate with a Diploma in Civil Engineering. My boss Peter Mayhew brought in his final exam paper from Imperial College in London. Wow his final exam questions were so much more difficult than mine. I would comment that from my employing many new graduate engineers, the Civil Engineering courses seems to have been dumbed right down. Many subjects that I had to pass such as geology, electrical engineering, engineering drawing and surveying etc are no longer on the syllabus. Recent graduates have no idea what RL or reduced level is nor can they draw or even sketch an idea!!

In 1970, I was appointed as Project Manager of a large multistorey building, the MLC building on the corner of Elizabeth St and Collins St in Melbourne. The foundations for this structure were designed on large diameter rock socketted piles, as I recall the first rock socketted piles for a building in Melbourne. This was my first encounter with Dr. Jack Morgan and a great learning experience it was. Jack was very adventurous and had designed all the sockets which were drilled and then hand mined in the Silurian mudstone based on a design shear strength of one third the U.C.S.

I had to call Jack every time a socket was completed. He would arrive and change into his overalls and he would be lowered down by an air winch to the base of the piles with his geologist hammer in hand to check the sockets. I accompanied Jack each time and learnt a lot from him.

One of the piles on this project encountered a dyke which was steeply dipping, at the top of the socket the good rock only covered about 20% of the pile area. This socket had to be hand mined a further 10 to 15 metres using shaft sets and timbers until the rock covered the whole cross section of the pile.

Needless to say this hand mining process took considerable time and was the last pile to be completed and was some 15 metres deeper than all the other piles.

Down the dyke with timbers & shafts set

In November 1970 I was married and still am!!! We spent our honeymoon in Lautoka, Fiji as I was Project Manager on the new Lautoka Hospital which was a gift from the British government to celebrate Fiji's Independence. Technically I was working for the British company of Frankipile Ltd as all contractors and consultants came from the UK.

Frankipile Ltd (UK) subcontracted the piling to Frankipile Australia Pty Ltd. The geology on this site was very complex with basalt boulders in a matrix of completely weathered basaltic clay. Enlarged base Frankipiles were the pile type used. The piles were driven until we encountered boulders, then we had to chop and core with large chisels to break up the boulders and to enable the piles to penetrate to their design depth of 15 metres. Whilst in Fiji, I became the defacto manager of Ground Test (now Douglas Partners), Don Douglas made frequent visits and we had many long phone calls while he educated me on the techniques required in carrying out the site investigations.

We carried out some very challenging site investigations. One was just out of Suva and I had to charter a helicopter to visit the site as it was covered in rice paddies and cane fields. The small Jacro S.I. rig also had to be airlifted in to the swampy site as there was no road access.

A second challenging site was for the hotel developments at Denarau Island close to Nadi Airport. I had to design a portable barge to cross a river to transfer the Jacro rig onto the Island and a sled on which to drag the rig from hole to hole. A local farmer was hired with his team of bullocks to drag the rig and drill tools, etc from hole to hole. Thanks to Don Douglas for educating me further.

After Fiji, my wife and I travelled via Hawaii, USA and Canada to the UK. In the UK I furthered my education whilst working with Frankipile Ltd reporting to the Managing Director Wally Rowland.

Wally assisted my education in allowing me to work on several UK sites; a very large contract installing thousands of Frankipiles at Llandavern in Wales; a very large bored pile contract installing thousands of large diameter bored piles for the new Covent Garden Markets. These piles were 900mm diameter and approximately 20 metres deep socketted into the London clay. I quickly had to learn the properties of the London clay to design the piles. Another very interesting project which taught me a lot was a major test piling programme to refine the design parameters for a complete redevelopment in front of Westminster Cathedral in London. Dr. Burland from the British Research Council in association with Arup were the geotechnical consultants. The site was very long and in two sections with a small road in between to give access to the Cathedral. We had to install two piles at each end of both sites i.e. 8 piles in all. At each location we installed one 1 metre diameter pile socketted into the London clay and the second pile was under reamed at the base to 2 metres at a shallower depth. We had to carefully hand clean each bored pile then lower Dr. Burland down to the base of each pile where he carried out plate load tests and took some tube samples for further testing. The piles were then reinforced and concreted and statically tested to 650 tonnes or failure. The testing verified that it was more cost effective to socket the piles rather than under ream and provided excellent soil parameters to enable the hundreds of working piles to be designed. Thanks to Dr. Burland and Wally Rowland I learnt a lot.

Westminster Cathedral Redevelopment – Installation, Instrumentation & testing to failure of L.D.B.Ps with B.R.S.

I was also very lucky to have two 3 week study trips to Pieux Franki in Belgium to learn all about bentonite under Dr. Wallays, Franki's Senior Geotechnical Engineering and Michelle Barr their Engineering Manager for all their Diaphragm wall contracts. The first visit was to Liege, the second was to Bruxelles. I learnt a significant amount from these two gentlemen which I still use today on our numerous Diaphragm wall contracts throughout Australia.

In 1972, I returned to Australia and was Project Manager for Queensland under Peter White in Brisbane. Although not an engineer, Peter White was a remarkable manager. Peter was a former milkman and taxi driver and an air force pilot during the Second World War. He was shot down twice and survived. His car was also hit by a train at a line crossing and was carried down 200 to 300 metres and survived. Peter was highly intelligent and had a great practical understanding of piling and the various techniques required in the various ground types. Peter was tenacious and gave his best to every situation and to every client; lessons which have helped me ever since working with him.

My geomechanic knowledge increased rapidly whilst in Queensland because of probably the smartest geotechnical engineer I have ever met, Peter McAnally. Peter was a genius in my opinion, his knowledge on all things geotechnical was amazing. Peter was the Manager of Ground Test (now Douglas Partners). I visited Peter on a daily basis where he checked many of my foundation designs, where they were wrong he would patiently work with me to explain why they were wrong and show the correct parameters to me, why they should be used and the appropriate method to be used in design. Peter was a great teacher and a lovely human being.

Peter left Ground Test to become a Professor and Lecturer at Queensland Institute of Technology now QUT where he taught many of today's geotechnical engineers. Peter and Bevan Boyce also wrote a Geotechnical reference book which I treasure and still refer to today.

On my return to Queensland to set up my own company I would visit Peter at home to seek his guidance on my designs (which he gave freely). My last visit to him was only about 1 hour before his untimely death of a stroke at a very early age. His early death was a tragedy to the Geotechnical community and profession.

My next adventure and rapid acceleration in learning was to take up the role as General Manager and Director of P.T. Frankipile Indonesia from 1976 to 1978/1979. When one is thrust into a foreign land with a completely different culture, different soil types and no knowledge of the language you need to learn a lot very quickly. My management and financial skills developed quickly. My geotechnical skills also had to develop quickly. To assist me I employed as a part time consultant Professor Zanussi. He was of great assistance in my learning the properties of the local soil types and also on how to design for earthquake loads and for settlement.

The volcanic clays in Jakarta were unusual and extremely deep. Therefore most piles and pile groups had to be design checked for settlement, something rarely done in Australia where the majority of piled foundations terminated on or into rock of some kind.

Professor Zanussi was a great teacher and help to me and we became very good friends.

In 1979 I returned to Australia to take up the position of State Manager for Victoria and Tasmania for Frankipile with the specific direction from the Managing Director Geoff Sexton and General Manager Peter Goodman to turn Victoria and Tasmania into a profitable company again as I had done in Indonesia. Winning work is easy, winning work and making a profit and doing the foundations properly is not.

I have always taken my responsibility to be ethical seriously, to make sure that any foundation pile, retaining wall, etc will not fail and be fit for service. To do the job properly costs more, so to do it properly and make a profit is often difficult, especially when our government agencies and many private clients believe that the cheapest price is the best. This is rarely true.

My knowledge accrued in Victoria once again, due to the foundation work on the Westgate Freeway through South Melbourne. This was a large contract to drive permanent steel liners to rock and to socket with long sockets in relatively weak Silurian rock. Due to the curved post tensioned superstructure, settlement and especially differential settlement was critical.

The whole contract was carried out with mutual respect and cooperation. We would discuss together special new tools for trialling before manufacture, designed and built special fan blade air lifts for cleaning, developed special techniques for getting the optimal bentonite properties and worked very closely with Dr. Jim Holden in making S.I.D., the Socket Inspection Device work. Jim was so intent on making S.I.D. better he would often phone me at home at about 9pm to see whether I thought his latest brain wave suggestion would work. This cooperation between client and contractor worked extremely well and S.I.D. became a fantastic tool to ensure perfectly clean sockets were provided. This was a very successful project for the client and the contractor and it made a profit.

In 1980 the ownership of Frankipile in Belgium changed. The new management terminated the then Managing Director, Geoffrey Sexton and Assistant Managing Director John Sexton. I was horrified that after 25 years of loyal and fantastic service, which had returned millions of dollars to the shareholders, they could be so callously dismissed.

I decided to leave Frankipile after 16 fabulous years and start my own company Wagstaff Piling Pty Ltd where my destiny was in my control, not some unknown overseas owner or shareholders.

Westgate Freeway – South Melbourne

The CRB (now VicRoads) had some very talented geotechnical engineers that had carried out significant research at Monash University, all of them obtaining PhD's on the way. These geotechnical engineers, Dr. Adrian Williams, Dr. Ian Johnson and Dr. Jim Holden had developed ground breaking knowledge of the performance of the silurian bedrock and the effects of bentonite on skin friction. They had very specific requirements which they clearly specified in their contract documents. As the contractor, we had to develop new drilling tools, new bentonite cleaning procedures to ensure the sockets were clean and met the design requirements.

In 1981 John Wagstaff Constructions commenced operations and carried out the first of many contracts, the Manly Marina redevelopment for the RQYS for Theiss Brothers Constructions.

Since its inception in 1980, John Wagstaff Constructions and Wagstaff Piling (WP) has always been an innovative and forward thinking Company in the foundation engineering field supported by its own engineers and like minded engineers external to the group.

The WP group has been encouraged to maintain and improve the standards in the theory and practice of geomechanics through sharing of information, communication, education and training within the group and with others in the area of geotechnical engineering.

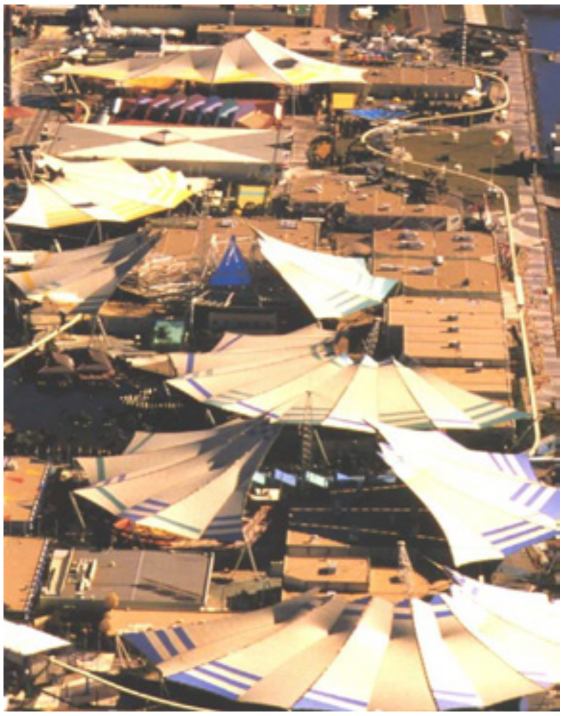
Over the last 4 decades, WP, as a privately owned Australian company, has completed in excess of 6000 projects Australia wide with a value exceeding over $2.0 billion dollars. The group has created a footprint in the community which covers a wide variety of projects in the civil, building, industrial and mining sectors.

Many of the projects have resulted in knowledge sharing which has contributed to an overall improvement in knowledge for the geomechanics profession. These projects include, but are not limited to, new developments such as in-situ soil mixing for ground improvements, pile integrity testing of bored piles utilizing thermal imaging, high and low strain dynamic testing of piles, thin/slender diaphragm wall construction and high durability stainless steel joints for segmental precast piles. WP has piled over 3000 bridges in Australia; you will probably drive over one of them today.

Innovation

Wagstaff Piling is very proud to be an innovative company for many reasons including:

1. Being the first company in Australia to introduce the Swedish Balken Piling system in 1982, a system comprised of:
   - Manufactured pre-cast segmental piles
   - New totally hydraulic Banut Piling machines with computer controlled hydraulic hammers.
   - A testing system using the Pile Driving Analyser and Capwap Analysis. This system has been developed and improved over the past 40 years and has greatly reduced the cost of foundation piling throughout Australia for the benefit of the community in general.
2. Completing the work for Expo '88. Expo '88 changed Brisbane from a large country town to an international city. The foundation for the project required thousands of precast piles, for the monorail, the buildings, board walk and the huge sails. The compression and tension loads for the sails were a real challenge. We designed and installed precast segmental piles driven at rakes of 45 degrees to the bedrock at up to 30 metres depth. Each pile was cast with a central duct to allow us to then drill into the rock and install a rock anchor through the pile to hold the massive sails from collapsing.



Expo '88 anchor piles

2010–2019

3. Introducing large diameter segmental cased secant piles into Australia in 1997 for the Cross River Tunnel under the Yarra River as part of the Melbourne City Link project.

   This project was awarded the "Outstanding Project Award" by the Deep Foundations Institute in New York in 2000. This is the only project in Australia to receive this prestigious award.

Secant piles – DFI award

4. Being awarded the 'Design and Construct' contract for another Melbourne City Link Project involving the elevated road structure following the Moonee Pond Creek from Royal Parade to the Yarra River in 1997.

   This project was at the time the largest contract undertaken by Wagstaff Piling and it involved the design, manufacture, installation and testing of 2500 No. precast segmental precast reinforced concrete piles.

Secant piles – cased – hard/hard

5. Introducing the first "Campile" displacement pile in 1998 at the Gold Coast and has been utilized on the Melbourne Aquatic Centre and many other projects.

Purpose built rig – Campile

6. Introducing the first Cutter Soil Mixing machine into Australia in 2005. Numerous projects throughout Australia have utilised this technique. The largest being a cut-off wall at Botany Bay in Sydney for the Orica Company. This project involved the soil mixing of a cut-off wall around the site 1 metre thick to the sandstone bedrock to depth of 30 metres to contain the contaminated site. Mass mixing techniques were used to cap the site with a bentonite- cement capping layer.

Soil mixing CSM method

7. Designing and building our own specified equipment to enable difficult foundation projects to be completed. Some of these include:

- Hydraulically controlled leader systems to attach to piling cranes to allow controlled raked piles in all directions and to allow extended reach, up, down and out from working on difficult sites.
- The design and manufacture of hydraulic piling hammers and sound attenuated hammers. We produced the quietest hammer in the world (to our knowledge) and have reduced the noise from 110 dBa to 75 dBa at 15 metres.
- The design and manufacture of specialised excavator mounted drill rigs to reach up, down and out 6 to 15 metres to allow installation of bored pile foundations for railway electrification poles in undulating terrain. This allowed trains especially the coal trains to keep running without interruption.
- The design and manufacture of specialised mini piling rigs to work in very confined sites.
- Introducing horizontal soil mixing techniques to depths of 500mm for working platforms for piling machines, railway lines, car parks, roads in general using both polymers and cement.
- Introducing mass mixing techniques using cementitious slurries to depths of up to 6 metres in swampy ground and to provide cut-off walls.
- Introducing specialised machines into Australia to install thin diaphragm walls 300, 400 and 500mm thick to meet the demands for space saving basement walls. The introduction of this wall to complement our larger diaphragm wall ability to construct 500, 600, 800, 1000 and 1200mm thick D walls has made our company probably the most prolific D wall company in Australia.

Purpose built rigs- long reach

Earlier innovations – hydraulic pile rig /hammer

Purpose built rigs – low headroom mini rig

Mass mixing technique

Diaphragm walls – small and thin

- Developing specialist tools and techniques to install M-lock bridges. Our methods allowed the construction of precast piles, precast headstocks and precast planks from abutment to piers to abutment by working from the constructed bridge progressively at bridge deck level.

Installation of M-lock bridges

Australia is blessed with many fine geotechnical engineers who have assisted me in many ways over the years, these include Professor Harry Poulos, Professor Mark Randolph, Allan McConnell, Peter McAnally (deceased), Neville Morrison, Julian Seidel, Don Douglas, David Klingberg (deceased) and many others.

I have also learnt much from my overseas contact with Professor Bengt Broms, Professor Bengt Fellenius, Professor George Goble (deceased), Dr. Frank Rausche, Carl-John Gravare and Professor Zanussi.

Attending local and international conferences has broadened my engineering knowledge and is recommended to all young engineers. The engineers who have and still work with our company are an inspiration to me and I have had the pleasure in passing on my knowledge and in return learning from them.

NATIONAL AND REGIONAL ACTIVITY

National Chairmen of the AGS

Name	Period of Office
D.H. Trollope	1971-72
C.R. Longworth	1972-73
A.D. Hosking	1974-75
W.E. Bamford	1976-78
P.C. Hollingsworth	1979-81
H.G. Poulos	1982-84
P.W. Mitchell	1985-87
N.S. Mattes	1988-90
M.C. Ervin	1991-93
G.R. Mostyn	1994-95
A.B. Phillips	1996-97
C.M. Haberfield	1998-99
J.P. Carter	2000-01
A.R. Leventhal	2002-03
M.B. Jaksa	2004-05
M.A. Woodward	2006-07
N.D. Benson	2008-09
G. K. Scholey	2010-11
S. Mackenzie	2012-13
D. Paul	2014-15
H. Acosta-Martinez	2016-17
S. Fityus	2018-19

Young Geotechnical Professionals (YGP) Conferences

Conference	Location	Year
1st ANZ YGP Conference	Sydney, Aus	1994
2nd ANZ YGP Conference	Auckland, NZ	1995
3rd ANZ YGP Conference	Melbourne, Aus	1998
4th ANZ YGP Conference	Perth, Aus	2000
5th ANZ YGP Conference	Rotorua, NZ	2002
6th ANZ YGP Conference	Gold Coast, Aus	2004
7th ANZ YGP Conference	Adelaide, Aus	2006
8th ANZ YGP Conference	Wellington, NZ	2008
9th ANZ YGP Conference	Melbourne, Aus	2012
10th ANZ YGP Conference	Noosa, Aus	2014
11th ANZ YGP Conference	Queenstown, NZ	2016
12th ANZ YGP Conference	Hobart, Aus	2018

Australia and New Zealand Regional Conferences

Conference	Location	Year
1st ANZ Conference on Geomechanics	Melbourne, Aus	1971
2nd ANZ Conference on Geomechanics	Brisbane, Aus	1975
3rd ANZ Conference on Geomechanics	Wellington, NZ	1980
4th ANZ Conference on Geomechanics	Perth, Aus	1984
5th ANZ Conference on Geomechanics	Sydney, Aus	1988
6th ANZ Conference on Geomechanics	Christchurch, NZ	1992
7th ANZ Conference on Geomechanics	Adelaide, Aus	1996
8th ANZ Conference on Geomechanics	Hobart, Aus	1999
9th ANZ Conference on Geomechanics	Auckland, NZ	2004
10th ANZ Conference on Geomechanics	Brisbane, Aus	2007
11th ANZ Conference on Geomechanics	Melbourne, Aus	2012
12th ANZ Conference on Geomechanics	Wellington, NZ	2015
13th ANZ Conference on Geomechanics	Perth, Aus	2019

GeoEng 2000

AN INTERNATIONAL CONFERENCE ON GEOTECHNICAL & GEOLOGICAL ENGINEERING
19-24 NOVEMBER 2000, MELBOURNE EXHIBITION AND CONVENTION CENTRE, MELBOURNE, AUSTRALIA

Vignette from *Australian Geomechanics* Dec 2000 (John Carter)

THOUGHTS FROM THE CHAIR

GeoEng 2000

I feel sure that the overwhelming majority of the 700 plus delegates who attended GeoEng2000 in Melbourne in November would agree with me that this was one of the best if not the best geotechnical conference ever held. This claim may be evidence of some hubris on my part, but I can assure you that it is supported by the numerous comments I have received from interstate and international colleagues alike. The difficulty of mounting a multi-disciplinary conference of this type should not be underestimated, bringing together as it did the three major themes of geotechnics and their representative societies, ISSMGE, ISRM and IAEG, as well as a number of other supporting bodies. This conference had something for everyone and a great deal for most. Obviously successes like this do not just happen; they are the result of careful planning and execution. I wish to extend to Max Ervin and the other members of his organizing committee the heartfelt thanks, firstly from the members of your National Committee, and also from the entire Society for a job very well done. Budgeted attendance was exceeded and our expectations of technical and social highlights were surpassed. In all respects this was a most successful conference, and aside from a little back trouble, amongst the most enjoyable I can remember. Well done, and take a bow Max and your wonderful organizing team!

Australasian Vice-Presidents of ISSMFE /ISSMGE

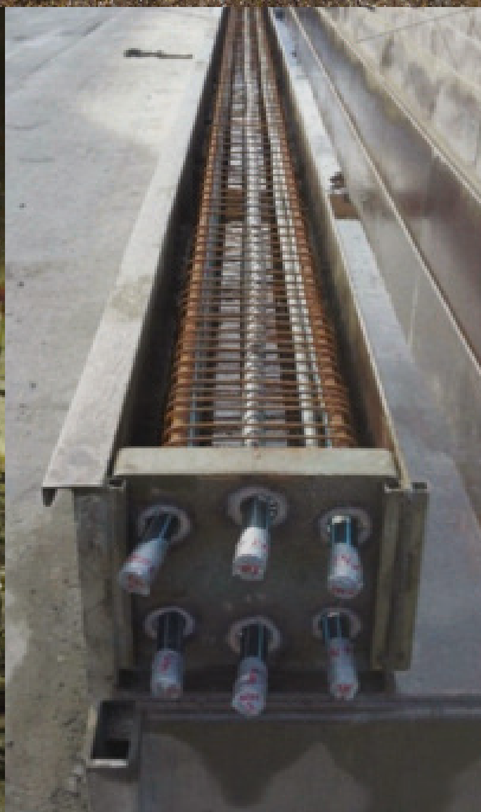
Name	Country	Period of Office
G.D. Aitchison	Australia	1957-61
J. Birrell	New Zealand	1961-65
D.H. Trollope	Australia	1965-69
E.H. Davis	Australia	1969-73
P.W. Taylor	New Zealand	1973-77
A.D. Hosking	Australia	1977-81
R.D. Northey	New Zealand	1981-85
J.H.H. Galloway	New Zealand	1985-89
H.G. Poulos	Australia	1989-94
M.C. Ervin	Australia	1994-97
M.F. Randolph	Australia	1997-2001
J.G. Murray	New Zealand	2001-05
J.P. Carter	Australia	2005-09
M.C.R. Davies	New Zealand	2009-13
M. Jaksa	Australia	2013-17
G. Alexander	New Zealand	2017-18
P. Robins	New Zealand	2019-21

Australasian Vice-Presidents of ISRM

Name	Country	Period of Office
L. A. Endersbee	Australia	1966-70
J.C. Jaeger	Australia	1970-74
A.J. Hargreaves	Australia	1975-79
W.E. Bamford	Australia	1980-87
I.W. Johnston	Australia	1988-91
M.J. Pender	New Zealand	1992-95
G. Mostyn	Australia	1996-99
C.Haberfield	Australia	2000-03
J. St George	New Zealand	2004-07
A. Meyers	Australia	2007-11
D. Beck	Australia	2011-15
S. Read	New Zealand	2015-19
S. Dehkhoda	Australia	2019-23

Australasian Vice-Presidents of IAEG

Name	Country	Period of Office
L.E. Oborn	New Zealand	1970-72
R. Gordon	Australia	1973-78
D.H. Stapledon	Australia	1979-82
D.H. Bell	New Zealand	1983-86
J.P. Trudinger	Australia	1987-90
J. Braybrooke	Australia	1991-94
W. Prebble	New Zealand	1995-98
B.G. Riddolls	New Zealand	1999-2002
F. Baynes	Australia	2003-06
A. Moon	Australia	2006-10
Ms A. Williams	New Zealand	2010-14
M. Eggers	Australia	2014-18
D. Johnson	New Zealand	2018-22



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