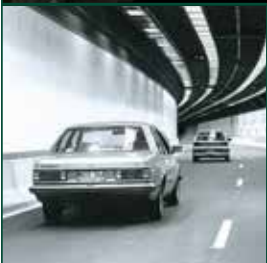





**AUSTRALIAN
TUNNELLING
SOCIETY**

50 *Years*



HERRENKNECHT AUSTRALASIA

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**PIONEERING
UNDERGROUND
TOGETHER**



President's foreword

Fellow tunnellers, welcome to our special edition celebrating the ATS's 50th year. In October 1972, following a request from the UN, the Australian Geomechanics Society created the "Australian Tunnelling Committee." Sometime afterward, the International Tunnelling Association was formed, of which ATS is a founding member.

For the last 50 years, and of course from before, Australia has been a tunnelling stronghold, not surprising for a nation that doubled in size in the 1850s chasing the precious lode, and with a nickname (Diggers) to suit. Australia's culture is outwards looking, with a significant percentage of immigrants, and we are open to trying new ways and methods from around the world. Our projects benefit from these new technologies.

In terms of the ATS itself, I was lucky to have inherited a very active and productive organisation. It has been a pleasure to see it evolve in the three decades I've been involved. The depth and breadth of this, and the two decades before, is captured beautifully in our 50-year timeline on pages 6 to 15. This captures, at a glance, the phenomenal amount that has been achieved by this volunteer organisation. An organisation run by dedicated and passionate tunnellers driven by the strong intention to make the tunnelling



industry safer and more efficient, and to make life easier for the communities it serves. Looking at this body of work as a whole not only confirms what I've long thought, that tunnelling does seem to attract the most enthusiastic nutcases that you see in engineering, but it makes me incredibly proud.

This special edition has been designed to highlight and document key moments in the growth of the ATS, and the key individuals who have contributed to it. It provides an opportunity for all members of the society, and other interested parties

across the industry, to reflect on their rich history and feel proud of their achievements and contributions. There are many fascinating personal accounts of tunnellers, why they got into the profession, what has kept them there and how and why they got involved in the ATS.

We've also compiled a series of articles that touch on the history in Australia of shotcrete, rock cutting, contracts, grouting, tunnel systems and safety. The intention is to create a timeless placeholder that offers future generations of ATS members the opportunity to look back and see their roots.

As always, the ATS Executive strives to provide value for its members and sponsors. This is the test we apply to all our decisions. If you have feedback on ATS activities or strategy, please do not hesitate to provide it. If you are reading this journal, are interested in tunnelling and want to support the tunnelling industry, please go to our website and join.

Lastly, thanks so much to all members of the ATS, past and present. I hope you enjoy this journal and the next 50 years of our society.

Harry Asche
President
Australian Tunnelling Society

GUEST EDITOR'S NOTE



As the editor and writer of this special 50th anniversary edition of the ATS journal, it has been a wonderful experience to do a deep dive into the history of the Society and learn about the direct impact ATS members have had on many of the essential infrastructure systems of Australia.

Nine months ago, when the ATS commissioned me to manage this project, I knew absolutely nothing about tunnelling (except that my young kids love it when we drive through them). Now I know that not only would our cities and towns be polluted, congested and devoid of fresh water without them, but I've learned just how passionate a bunch of people tunnellers actually are.

We have compiled many great stories in this special journal and I am full of admiration for you all, particularly those ATS members whose countless volunteer hours have enabled this Society to succeed through its first half century, and established a solid platform from which it can thrive through its next.

I'd like to thank all the contributors to this journal and particularly acknowledge the efforts of the ATS Journal Committee - Charles MacDonald, Tom Roper, Andrew Ridout and Rachael McCarrison. You have all been incredibly generous in assisting with my endless questions and requests for information and I look forward to working with many of you in the future in the capacity of my new part time role of ATS Communications Coordinator. Tunnelling seems to have gotten under my skin too.

Penny Jones
Freelance writer and editor

David Lees...

Spreading the word

My ATS story started when I emigrated to Australia with SMEC in 1995. After a short stint in Cooma, I was transferred to Sydney to work on the LPG Storage Cavern at Port Botany, NSW. Because I had previously been a keen participant of the British Tunnelling Society (BTS), I was keen to join the ATS or AUCTA (Australian Underground Construction and Tunnelling Association) as it was then known.

I made my presence known and was invited to join the Sydney committee and then the National Executive Committee. At my first National Committee meeting I remember complaining about the quality of the AUCTA Journal and being asked by the Chairman, Alan Chappel, if I could do better. I said yes and was soon appointed Editor – a post I have held ever since.

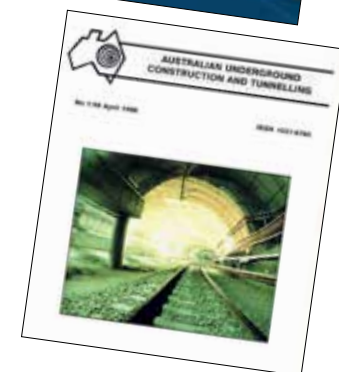
I remember the first journal I produced. Our publishers were Paragon Printers in Canberra and I used the conference room in the Elgas site office to lay out all the articles. The process was nowhere near as easy as it is now because everything was done by hand. We didn't even use electronic files.

The cover shot of my first journal was stunning. It was of the new Olympic Park Station and must have been so awe-inspiring because I completely missed a typo in the title. It went to print with Australian Underground Constuction and Tunnelling Association. I remember proudly showing a copy to my wife Jacqui who picked up the typo immediately. I had missed the R out of Construction! Once I'd seen the error, I couldn't unsee it, so I made some sticky labels and applied them, by hand, to all the 400 copies we had made. After that, I asked Jacqui to proofread everything.

Over the years we have changed the style of the journal but always endeavoured to present Australian, New Zealand and Asian tunnelling news (about projects of interest to tunnelling professionals in Australia and New Zealand); underground mining news (particularly developments that could impact on tunnelling or where mining projects provided opportunities for tunnelling professionals); historic projects; and news from the groups and the International Tunnelling Association. I also continue to build a database of existing and future projects.

Another achievement was producing and publishing two books: the History of Australian Tunnelling and the History of Tunnelling in New Zealand. I also helped initiate the David Sugden Award to encourage young engineers to write technical papers. This award was inspired by the Harding Prize in the BTS.

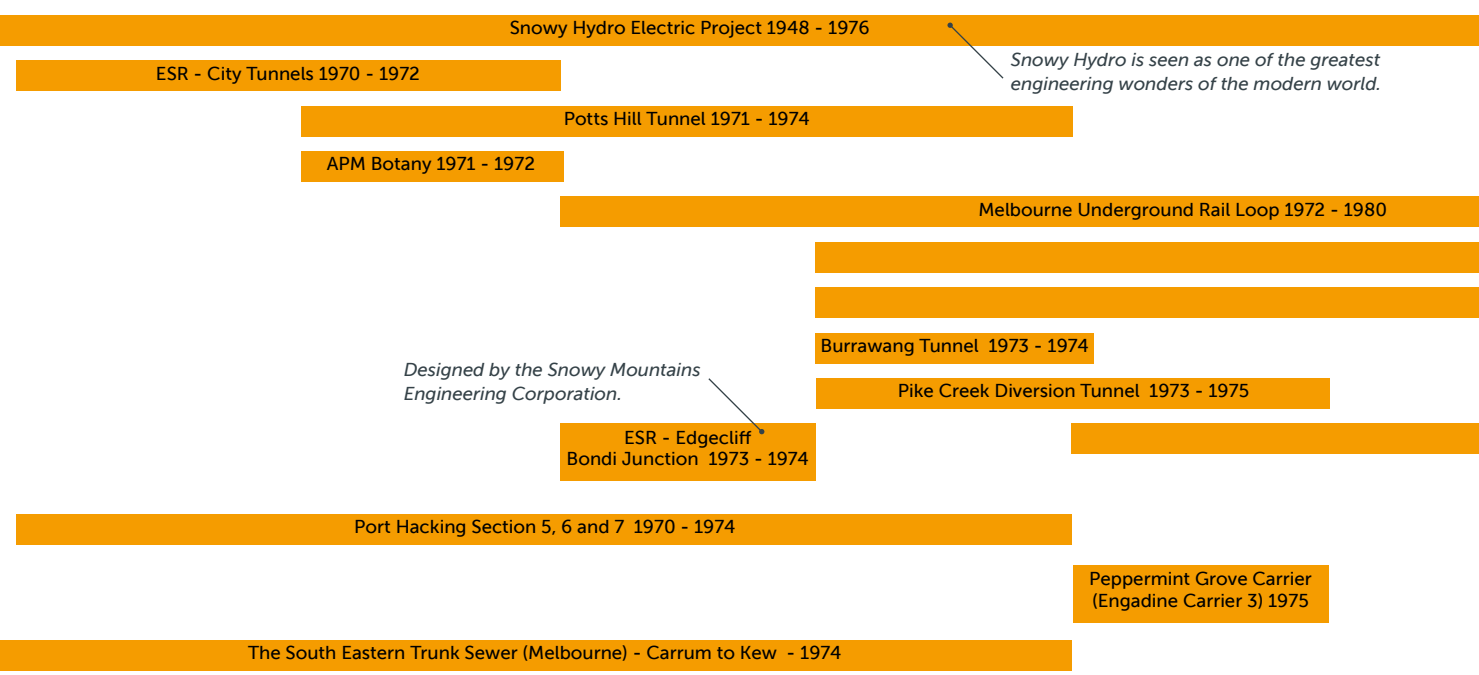
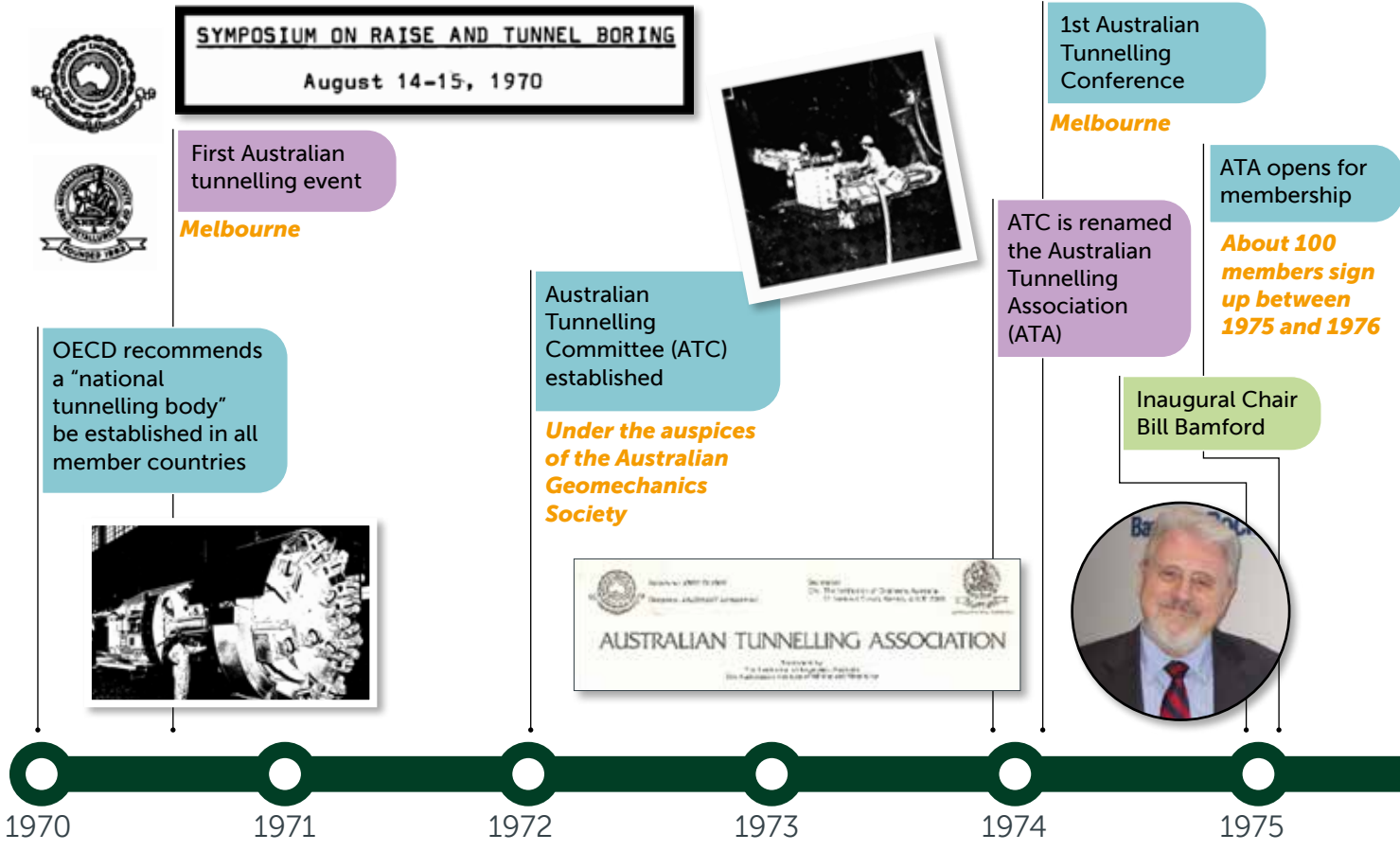
I'm also proud of developing ATS short courses, the first was held at UNSW Sydney and from there they have continued and evolved. But by far the greatest and most lasting benefit I've gained from my work and experiences at the ATS are the friendships I've made with like-minded professionals all over Australia and New Zealand. I hope this will continue for many years to come.

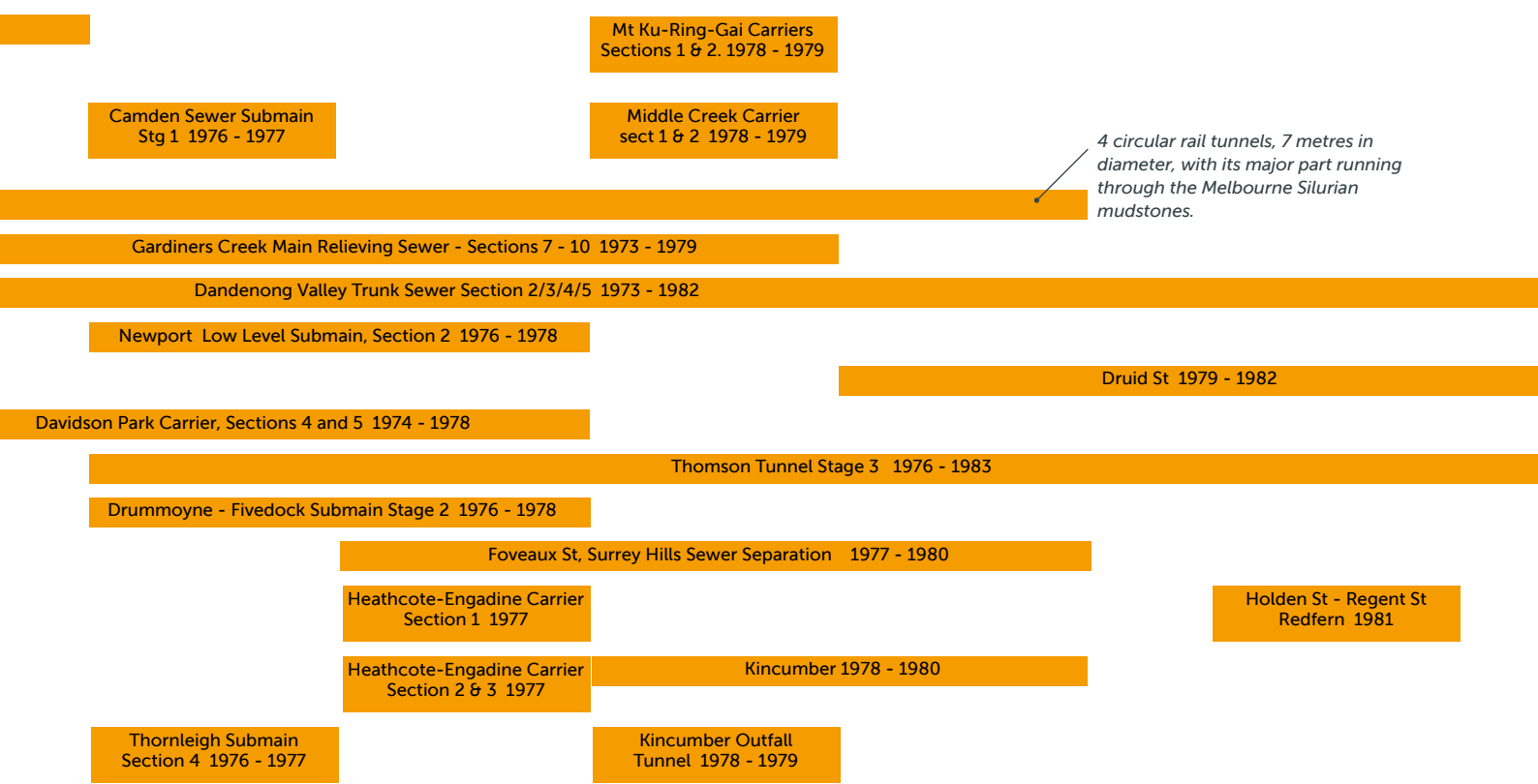
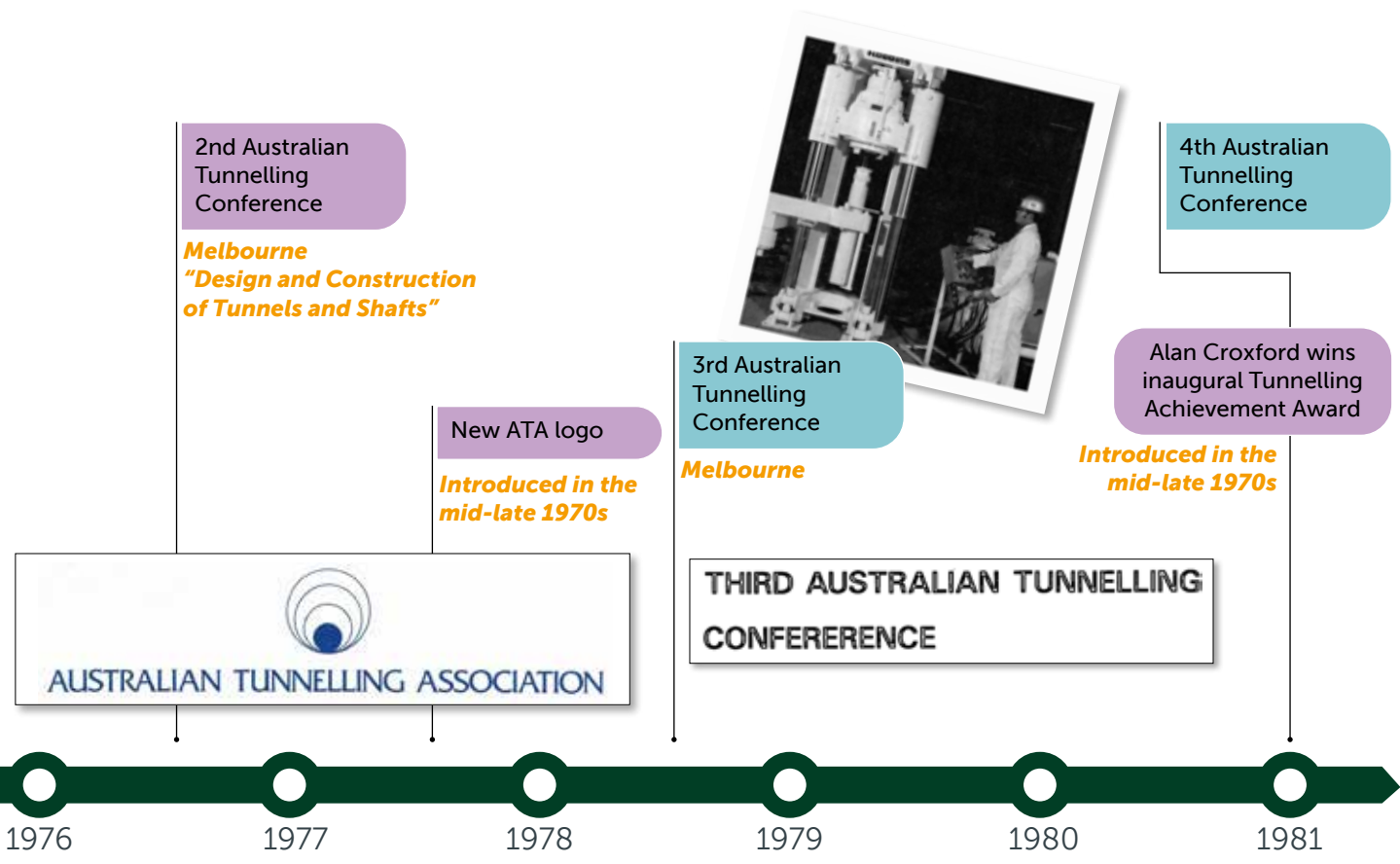


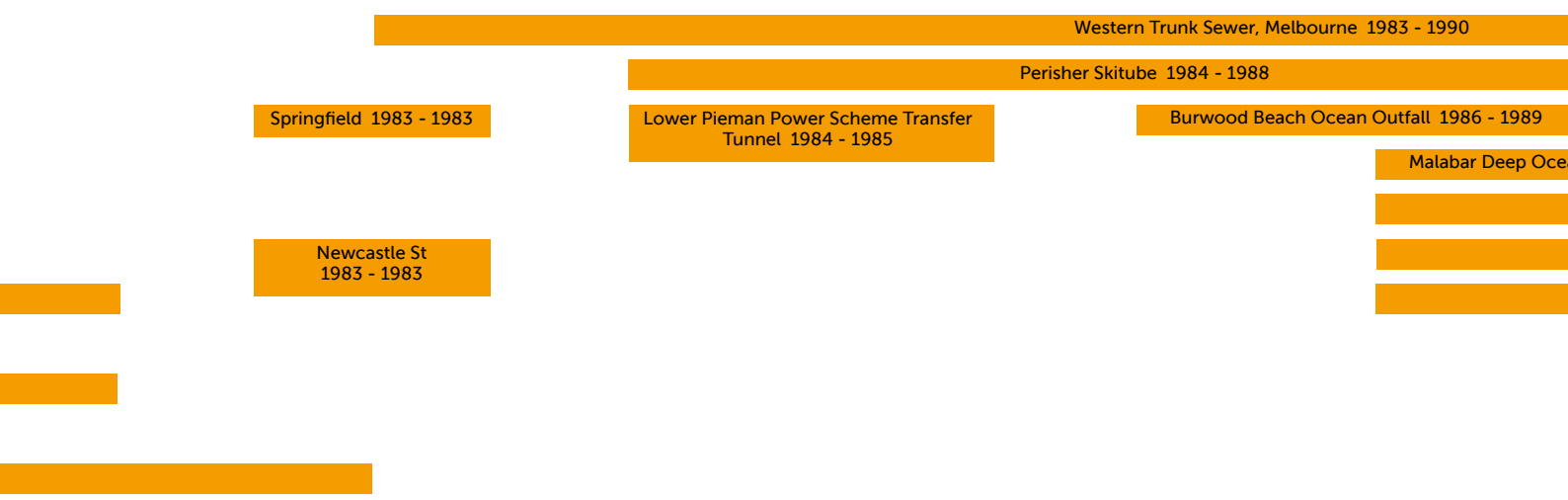
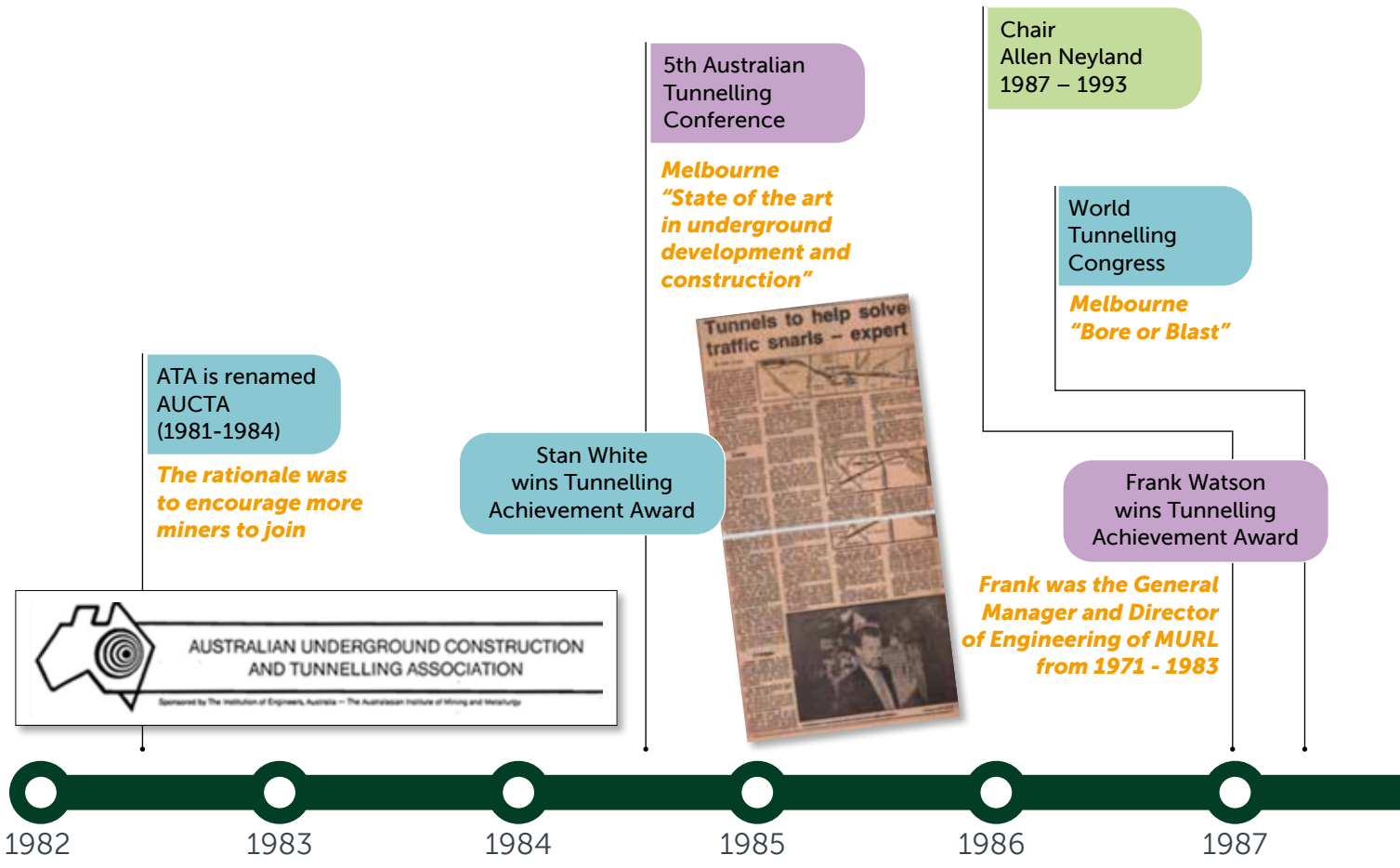
David Lees' first journal. So in awe of the photo, he missed a typo in the heading. Look closely and you can see the outline of one of the 400 stickers he had printed to rectify his mistake.

50 years of tunnelling

RE-SHAPING CITIES USING UNDERGROUND CONSTRUCTION







VIII AUSTRALIAN TUNNELLING CONFERENCE

'FINDING COMMON GROUND'

8th Australian Tunnelling Conference

Sydney

Allen Neyland wins Tunnelling Achievement Award

Chair
P. F. Howlett
1993-1994

AUCTA gives bicentennial lecture to the BTS

Lecture given by Chris Windsor



6th Australian Tunnelling Conference

Sydney

7th Australian Tunnelling Conference

Sydney

First female Chapter Chair
1993* - 2001

Margaret McMahon is the first female Chapter Chair and the first female to sit on the National Exec.

*It could have been earlier than 1993

"THE UNDERGROUND DOMAIN"

COST EFFECTIVE TUNNELLING IN THE SYDNEY BASIN

1988

1989

1990

1991

1992

1993

North West Sewer 1991 - 1998

Prospect to Pipehead Tunnel 1991 - 1994

The Sydney Harbour Tunnel cost \$580 million dollars which wouldn't get you much today!!

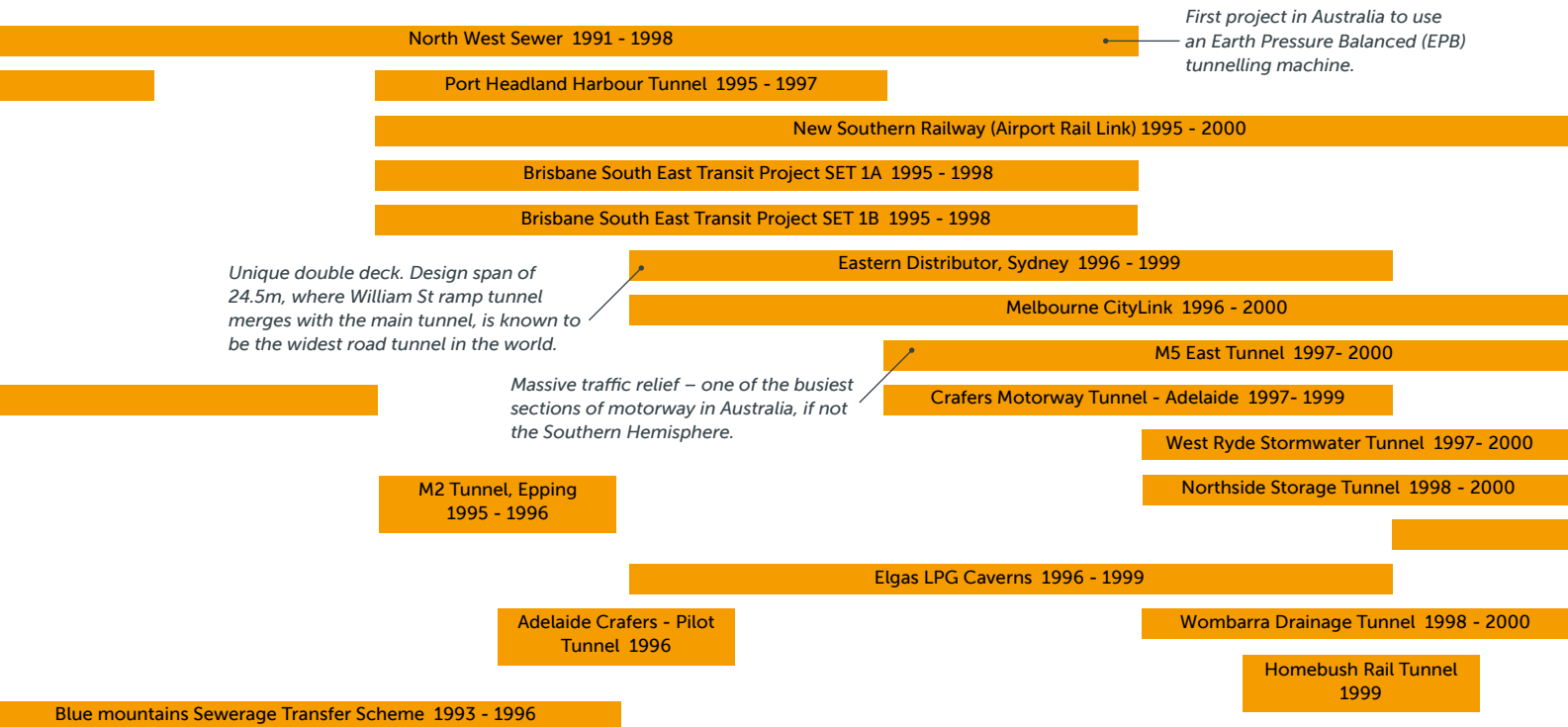
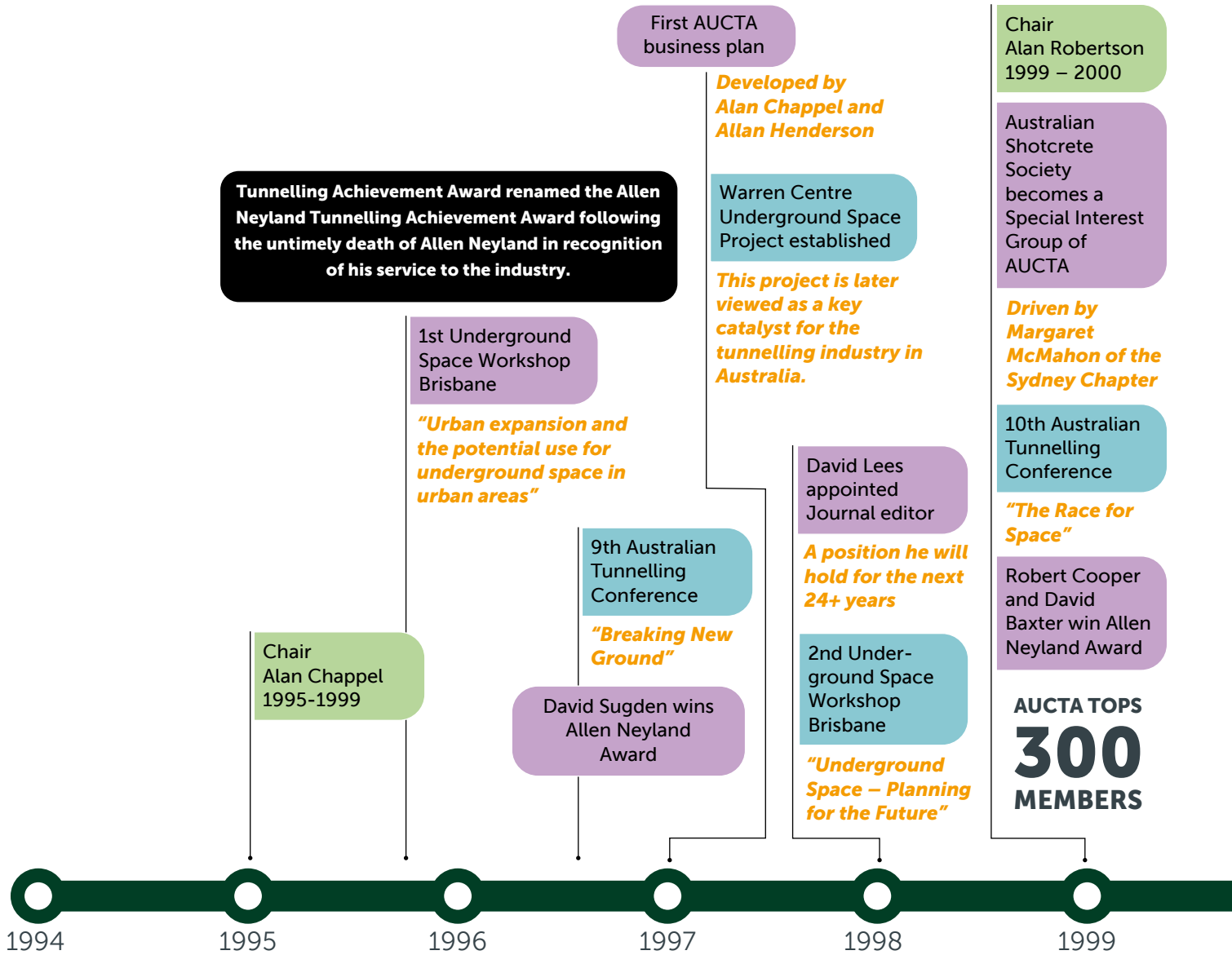
Sydney Harbour Tunnel 1987 - 1991

Boomerang Creek Tunnel 1987 - 1990

Bondi Outfall Tunnel Sewer 1987 - 1991

Opera House Underground Carpark 1990 - 1992

Brisbane Rail Tunnels 1991 - 1995



AUCTA Journal gets a new look

Redesign to coincide with the WTC 2002



AUCTA corporate membership introduced

First to sign up include: Atlas Copco Construction, Ove Arup & Partners, Peabody Resources, Thies Contractors, Terratec Asia Pacific, Transfield, Castrol Australia, Onesteel Reinforcing, Walter Construction Group and XYPEC Australia

AUCTA Workshop at GeoEng2000

"Planning for Tunnelling in the Urban Environment"

Chair Garry Ash 2000-2002



International Shotcrete Conference Hobart

"Recent developments in shotcrete technology"

AUCTA launches first website www.aucta.com.au

David Sugden receives an Officer of the Order of Australia award

AUCTA tops 450 members

The lack of student membership is seen as a problem. It's decided that it will be offered free to them.

World Tunnelling Congress and 11th Australian Tunnelling Conference

Modern Tunnels - Challenges and Solutions

Mike Wille wins Alan Neyland Award

Chair Peter Kessler 2002 - 2005



Anmol Bedi wins first David Sugden Young Engineers Writing Award



Young Tunnelling Professional added to the National Exec
Anmol Bedi elected to the role

WA Chapter formed

Inaugural Chair Eric Hudson-Smith

National Safety Sub Committee formed



Tina Caldwell wins David Sugden Award
Alan Chappel wins Allen Neyland Award

Chair Tony Peach 2005 - 2006

12th Australian Tunnelling Conference

"Tunnelling and Underground Construction for Better Cities"

Formation of the New Zealand Chapter

Society renamed to the Australasian Tunnelling Society (ATS).



2000

2001

2002

2003

2004

2005

Cudgen Road Tunnel 2000 - 2002

Epping Chatswood Rail Link 2001 - 2008

Energy Australia 132kV Cable Tunnel 2001 - 2003

Cross City Tunnel, Sydney 2003 - 2005

Lane Cove Tunnel 2003 - 2007

New Metro Rail Package F 2004 - 2006

EastLink - Mullum Mullum Tunnel 2004 - 2008

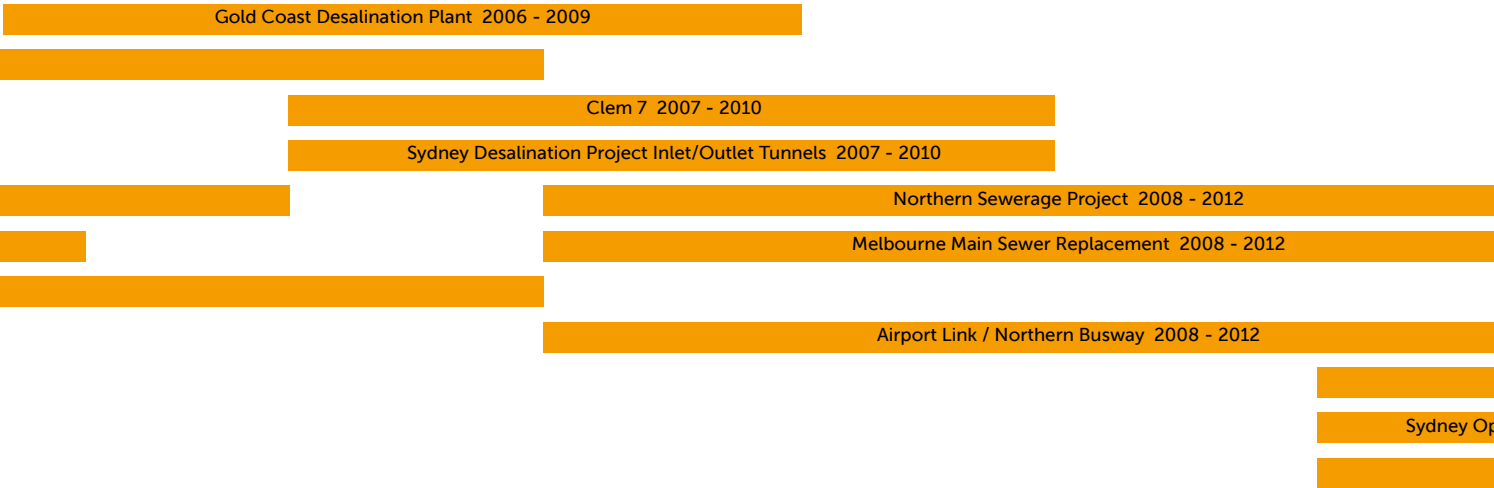
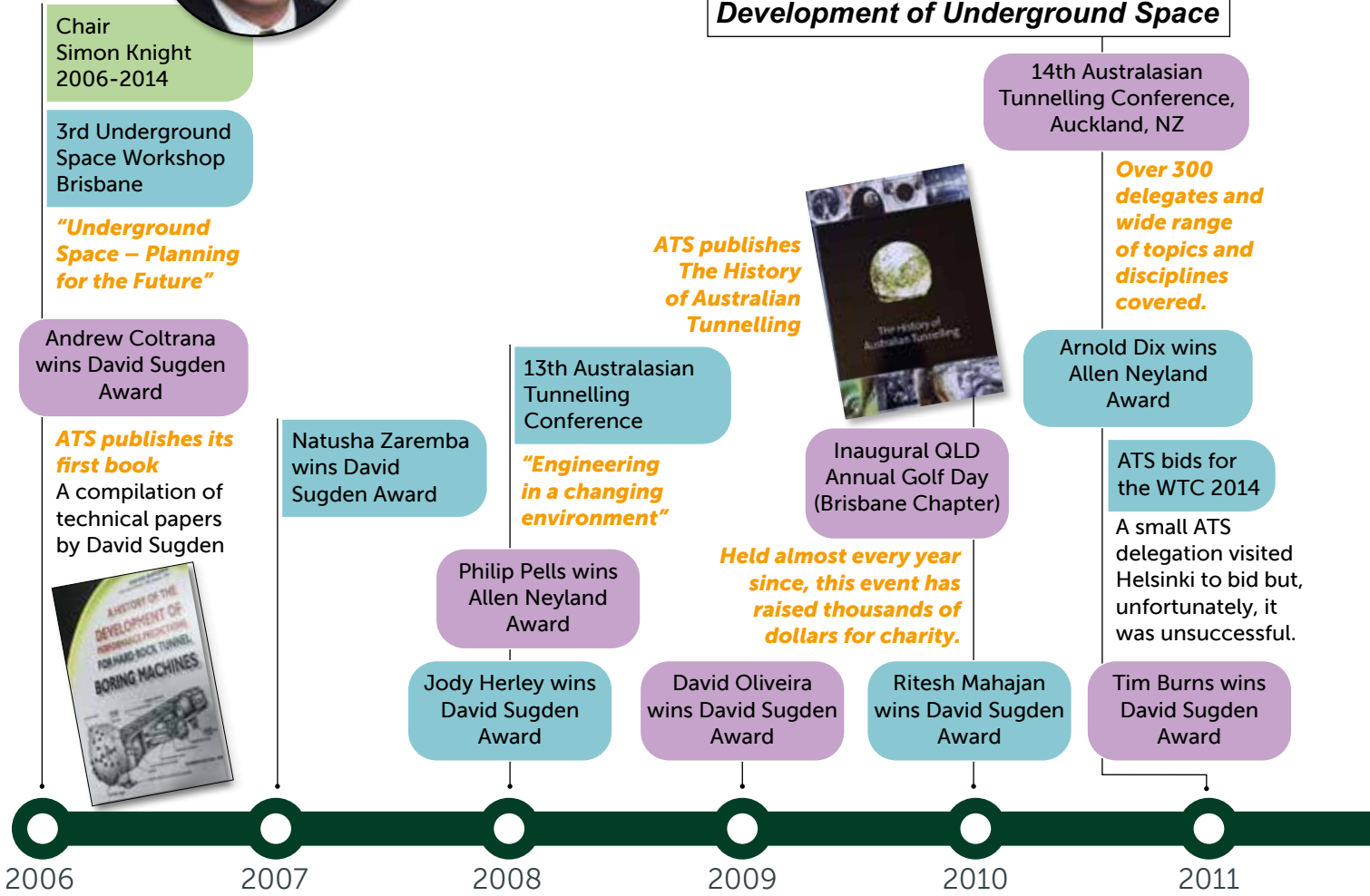
Brisbane S1 Sewer 2002 - 2005

Perth Main Sewer Replacement, Section 3 1999 - 2000



Farewell David Sugden - July 2011
 David was the driving force behind the successful design of mechanical full-face rock excavation machinery over a number of years, resulting in the construction of countless tunnels all across the world.

Development of Underground Space





With an increasing pipeline of work in Australia, the focus will be to "remain relevant to members while attracting new professionals to the industry."

ATS publishes the book *The History of New Zealand Tunnelling*
Edited by David Lees

ATS Young Members (ATSym) Sub Committee established

Initiated by Jurij Karlovšek who became the inaugural National Chair

Tunnelling Short Course Melbourne

Proposed new National Tunnelling Code of Practice

ATS strongly supported the proposal and provided a considered response to the draft.

Jurij Karlovšek wins David Sugden Award

Inaugural NSW Annual Golf Day

Mahdi Zoorabadi wins David Sugden Award

4th Underground Space Workshop

"Highlighting the need and opportunities for underground space in Brisbane over the next few decades."

Chair Ed Taylor 2014-2019

15th Australasian Tunnelling Conference

"Underground Space – Solutions for the Future"

Doug Maconochie wins Allen Neyland Award



ATS starts LinkedIn page

Simon Strong wins David Sugden Award

ITA Young Members established



ATS tops 600 Members

New look ATS journal launched

Now published by leading technical magazine Tunnelling Journal.

ATS launches Facebook page

Daan Van Den Broecke wins David Sugden Award



First ATSym social event. Held in Sydney. 76 attendees, including 25 undergraduate students

Mini symposium on Metros



Ed Taylor wins Allen Neyland Award

Bid to host the 2020 WTC in Melbourne
Only narrowly lost to Malaysia.

16th Australasian Tunnelling Conference

ATS's international impact

Arnold Dix appointed to the ITA Executive Council and Keith Bannerman appointed to the ITAym Steering Committee.

Russell Connors wins David Sugden Award

2012

2013

2014

2015

2016

2017

Gladstone LNG Crossing 2012 - 2014

Wynyard Walk 2012 - 2016

Sydney Metro Northwest Tunnels Stations Civils Contract 2013 - 2017

The tunnel construction involved 28 roadheaders being used across the project, making this the greatest number of roadheaders used on a single project anywhere in Australia.

WestConnex Stage 1B - M4 East 2015 - 2019

WestConnex Stage 2 - New M5 2015 - 2020

NorthConnex 2015 - 2020

Forrestfield Airport Link 2016 - 2022

Perth City Link 2011 - 2014

Opera House Vehicle Access and Pedestrian Safety 2011 - 2014

Legacy Way 2011 - 2015

Undergraduate Engagement

ATS NSW presented at universities across Sydney to highlight tunnelling as a potential career.

ATSym social

"Tunnelling across generations"
Over 300 attended

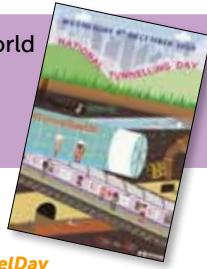
Engineer of the Year Award

ATS Queensland Chair Dr Harry Asche, awarded Queensland Division Professional Engineer of the year at the Australian Engineering Excellence Awards

Matthew Bennett wins David Sugden Award

Making World Tunnelling Day more inclusive

ATSym and ITAym get the hashtag #WorldTunnelDay trending on the 4th of December. Traditionally celebrated as St Barbara's Day, the young members wanted to make it appeal to a secular audience too.



ATSym David Sugden Roadshow

Senthilnath, G. T wins David Sugden Award

Air Quality Working Group (AQWG) documents launched and lauded.

ATS Tunnel Design Guideline published

A thorough general reference guide for elementary tunnel design created by ATSym.



Embracing online communications

ATS adapts to the new way of working and hosts several online presentations regularly attracting 500+ attendees



The AQWG developed 12 papers in a project that won ITA "Safety Initiative of the Year" award.

Daniel O'Kelly wins David Sugden Award

Tony Peach wins Allen Neyland Award



Diane Mathers becomes first female Qld Chapter Chair



Chair Harry Asche 2019 - ongoing

Tunnel Systems Workshop

The workshop led directly to the establishment of the Tunnel Systems Sub Group in 2021.

17th Australasian Tunnelling Conference - POSTPONED

Victorian Tunnelling Centre opens

Australia's first dedicated tunnelling training centre was established with the help of many ATS members

Australian company wins Major Project of the Year at the ITA awards

John Holland CPB Ghella JV – Tunnelling and excavation works for Sydney Metro City & Southwest project



NZ creates its own society and ATS is renamed the Australian Tunnelling Society (ATS)

Austrroads Road Tunnels Taskforce

ATS joins taskforce to help update the Guide to Road Tunnels document

2018

2019

2020

West Gate Tunnel 2018

Melbourne Metro Tunnels and Stations PPP 2018 - 2023

WestConnex Stage 1B - M4 East 2015 - 2019

WestConnex Stage 2 - New M5 2015 - 2020

NorthConnex 2015 - 2020

Forrestfield Airport Link 2016 - 2022

Sydney Metro City & Southwest Tunnels Stations Excavation Contract 2017 - 2021

Snowy 2.0 2019

WestConnex Stage 3 - M4-M5 Link 2019 - 2023

Cross River Rail Tunnels & Stations Development PPP 2019 -

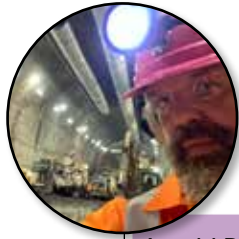
17th Australasian
Tunnelling Conference

**Melbourne (during a miraculous
break between lockdowns and border
closures)**
"Innovating the next 50 years"



Josh Barry wins Young
Tunneller of the Year at the
ITA Awards - Dec 2020

**Women in
Tunnelling Sub
Group established**
*This was almost
immediately changed
to the Diversity in
Tunnelling Sub Group
Tunnel Systems Sub
Group in 2021.*



Arnold Dix elected as President
of the ITA

ATSym win EA's
President Prize

Sponsorship snapshot

**ATS sponsorship has been growing
steadily since initiated in 2000**
6 Platinum Sponsors
45 Gold Sponsors

Ivan Haryono wins
David Sugden
Award

Harry Buchanan wins
David Sugden Award

Please note: this information has been pulled from many different source documents, some of which conflicted (including name spellings). While we have endeavoured to be as accurate as possible, if you spot an error, we apologise unreservedly. Feel free to contact us to set the record straight in a future journal and so we can update the timeline. We would also like to thank David Lees for keeping track of all the tunnelling projects in Australia.

2021

2022

2023

WestConnex Stage 3B - (Rozelle Interchange) 2019 - 2023

Kidston Pumped Hydro 2021

Brisbane Metro 2021

Western Harbour Tunnel Phase 1 2022 -

Sydney Metro West Central package CTP 2022 -

Sydney Metro West Western package WTP 2022 -

ATS beginnings

Today's Australian Tunnelling Society

(ATS) can trace its roots back to the 1948 establishment of the National Committee on Soil Mechanics and Foundation Engineering by the Institution of Engineers Australia (IEAust). This was subsequently restructured and renamed as the National Committee on Geomechanics in 1968, to reflect the growing involvement of rock mechanics and the mining industry, under the joint sponsorship of the IEAust and the Australasian Institute of Mining and Metallurgy (AusIMM).

Towards the end of the 1960's, with the high-profile Snowy Hydro Scheme (and its incredible 225 kilometres of tunnels) nearing completion and several other major tunnelling projects under construction or consideration, tunnelling in Australia was increasingly seen as an industry in need of its own agency.

This need was apparently global because in 1970, an Advisory Conference on Tunnelling, sponsored by the Organization for Economic Cooperation and Development (OECD), was held in Washington, DC. One of its principal recommendations was that a national tunnelling agency to "define and promote areas of research and development in tunnelling" should be established in all OECD member countries.

When the Australian Government received this advice, it asked the Department of National Development to take the lead. They referred it to the IEAust who decided the newly formed Australian Geomechanics Society (AGS) should be responsible. (The AGS had been established following the first Australia-New Zealand Conference on Geomechanics in Melbourne in 1971.)

In parallel to all the high-level official discussions on governance, mechanised tunnelling on the ground was continuing in earnest and the need to disseminate the latest knowledge, innovations and expertise was growing ever more important. It was in this context, in 1970, that Dr Bill Bamford was given the go ahead by the AusIMM to organise a two-day symposium on Raise and Tunnel Boring in Australia at the University of Melbourne. The event was an adjunct to the Annual Conference of the AusIMM, and the proceedings were retrospectively



The Snowy Hydro Scheme was one of the reasons that tunnelling in Australia was seen as an industry in need of its own agency.



Digging the pilot tunnel for the Melbourne Underground Rail Loop (MURL) in August 1972. MURL was another of the reasons that tunnelling in Australia was seen as an industry in need of its own agency. Note the cigarette – a sign of how much society (and underground safety, has changed since the 70s. Photo: Public Record Office Victoria

recognised as the first publication of the (yet to be established) Australian Tunnelling Association (ATA).

By 1972, the OECD recommendation had filtered through the various Australian agencies and was the responsibility of the AGS's National Committee, chaired by Prof. Hugh Trollope and later by Sandy Longworth. The AGS held a one-day seminar in Melbourne to hear a series of papers on the state-of-the-art of tunnelling, and to discuss the scope, objectives

and terms of reference of the proposed committee. (This was later recognised as the second publication of the ATA.)

As a result of the interest expressed by the participants, the AGS agreed to set up an Australian Tunnelling Committee (ATC), whose scope and activities might not necessarily be restricted to normal learned society functions, but could include broader socio-economic aspects. The ATC was then established, comprising Bill Bamford, Sandy Bennet, Arthur

Cairncross, Charles Gerrard, Warren Peck, Neville Smith and Frank Watson, with the task of establishing an inaugural program of activities in the tunnelling area. In 1973, the committee decided to organise a two-day conference called "Re-Shaping Cities Using Underground Construction," which was held in Melbourne in October 1974. This was retrospectively recognised as the first Australian Tunnelling Conference.

Also in 1974, the International Tunnelling Association (ITA) was inaugurated, and Australia not only agreed to become affiliated with it, but was one of the founding members. This was the point at which the ATC transformed into the representative Australian body called the Australian Tunnelling Association.

The AusIMM's CEO, Miss Beryl Jacka, who had enthusiastically thrown her support behind the fledgling tunnelling group, offered to host the secretariat, but the IEAust insisted on doing this on the grounds that more members of ATA were IEAust members than AusIMM members. The formal agreement between the two sponsoring bodies stated that any operational losses were to be equally shared by both

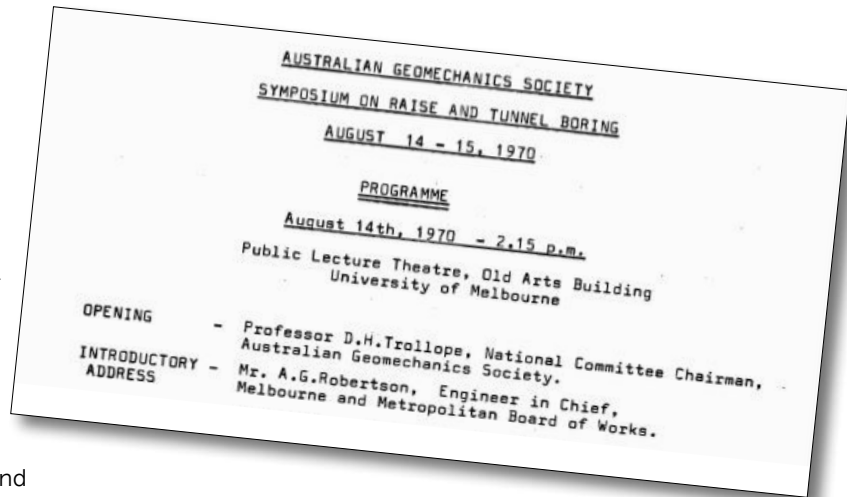
sponsoring bodies.

In 1975, shortly after Bill Bamford had taken office as the inaugural ATA National Chair, the first activity planned by the new ATA was a conference on "Design and Construction of Tunnels and Shafts."

This event was organised by Bill Bamford, Charles Gerrard, Bob Horseman, Warren Peck, and Frank Watson and was held in Melbourne in August 1976. It was retrospectively

recognised as the second Australian Tunnelling Conference.

With a clear remit and a burgeoning industry to service, Australia's tunnelling agency was now well underway.



AUSTRALIAN TUNNELLING ASSOCIATION

ATA logo – mid-late 1970s - 1981

DEFINING EXCELLENCE

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Equipment Service & Technical Support



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On-Site Technical Support

Kick starting the society

Dr Bill Bamford is recognised globally as a world leader in the field of specialised rock testing with a lifetime of experience and research devoted to the area. He is a founding member of the ATS and was the first Chair between 1975-1978.

"In 1957, when the Space Age dawned with Sputnik 1 going into orbit around the world, and when the first hard-rock TBM had been pioneered by Jim Robbins, only five years earlier, I first worked underground. To be precise, I worked in the Tumut 1 underground power station and its tailrace tunnel in the Snowy Mountains Hydroelectric Scheme as an Engineering Geologist. Later I worked on the Geehi Dam and Murray 1 Underground Power Station investigations, and was resident geologist on the Murrumbidgee-Eucumbene Tunnel. (Interestingly, fast forward 60 years and I was back, testing the same rocks, investigating the Snowy 2.0 project.)

I worked for the Snowy until 1960, when I joined the staff of the Victorian Mines Department and started the geotechnical investigations work for the Melbourne Underground Rail Loop (MURL). I worked on this and a variety of other mining and tunnelling projects until 1967, when I joined the University of Melbourne as the first Lecturer in Rock Mechanics to be appointed in Australia. This was a real honour and a great opportunity because Australia's tunnelling industry was booming. Technical innovations were thriving and throughout the 70s and 80s we were arguably world leaders in several areas including the use of TBMs, roadheaders, rock bolting and shotcreting. Certainly, the 'Melbourne Shield,' designed locally, was a term that was known globally during this time.

Because of this momentum, the first official tunnelling event I organised, the two-day Raise and Tunnel Boring in Australia symposium at the University of Melbourne in 1970, was a great success. A total of 19 papers were presented to an audience of just over 200 and the next day participants got the opportunity to visit the South-East Trunk Sewer and the Dandenong Valley Trunk Sewer. I believe the success of this led the AusIMM to nominate me as their representative on the National Committee of the AGS from the time it was formed in 1971 onwards.

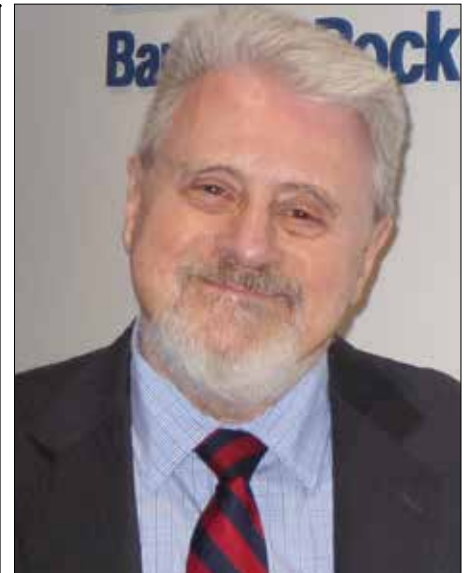
When the Australian Tunnelling Committee (ATC) was formed in 1972 it was under the auspices of the AGS, and its founding statutes stated that the chairman of the new tunnelling body

'should be the Chairman of the AGS, or his nominee.' When I assumed the position of National Chairman of the AGS in 1975, I did try to find a suitable nominee to be chairman of the ATC, but eventually took the job myself. I would say that during my three years as chairman of both societies, I spent more effort getting the ATC established than continuing the already well-established AGS.

Following the 1974, IEAust seminar in Melbourne, called Re-Shaping Cities Using Underground Construction, which attracted around 15 invited papers and was very well attended, we decided that organising a conventional tunnelling conference should be our next priority. We held this in 1976 in the National Science Centre (Clunies-Ross House) and it was called "Design and Construction of Tunnels and Shafts." There were 21 papers presented and over 200 people came along. The success of this conference established a regular series of successors, at two or three yearly intervals which has continued ever since. During this period, we also changed the name to the Australian Tunnelling Association (ATA) and opened it up to membership. By the mid-seventies we had around 100 members.

Throughout the 25 years I was actively involved with the ATS (as it eventually became known), I served as a member of the National Committee from 1975 until 2002, and on the Victorian Chapter Committee from 2011 until 2015, but I was also involved in the International Tunnelling Association (ITA) too. I was on the organising committee for the 1987 World Tunnel Congress in Melbourne. My most memorable moment of that conference wasn't so much the tunnelling content, it was sitting next to Sir David Smith at the dinner, the man who had read the Governor-General's proclamation that essentially dismissed the Prime Minister Gough Whitlam in that iconic political moment of 1974.

Between 1994 and



1999 I represented Australia at the annual meetings of the ITA and World Tunnel Congresses, and at the Oslo meeting in 1999 I presented Australia's successful bid to host the World Tunnel Congress in 2002. To supplement my presentation, I had brought all these little koalas to give out which everyone loved. Even the people who voted against us wanted a koala! We only defeated Singapore's rival bid that year by two votes and I've always wondered if the koalas swung it for us. In actual fact, they were the only thing I had to give out because DHL had lost the brochures the ATS had developed that detailed how wonderful a place Sydney was and why we should have the congress there!

Although it was hard work at times, I really enjoyed helping establish the ATS and then helping out at the national and international scale. I'm particularly proud that my peers thought so much of my contribution that I was made an honorary life member of the Society in 2000."

Melbourne Underground Rail Loop - Exploratory pilot tunnel beneath Latrobe Street 1966 - Preparing in-situ testing. Bill Bamford stands in the centre, wearing a white hat, overalls and a miner's lamp battery on his belt.



A person in silhouette, wearing a hard hat and carrying a bag, walks away from the camera through a large, circular tunnel. The tunnel walls are illuminated with a warm, golden light. In the distance, a series of smaller, colorful tunnels (blue, green, yellow) are visible, creating a sense of depth and progression. The overall atmosphere is one of industrial scale and human presence.

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The state of play in 1979

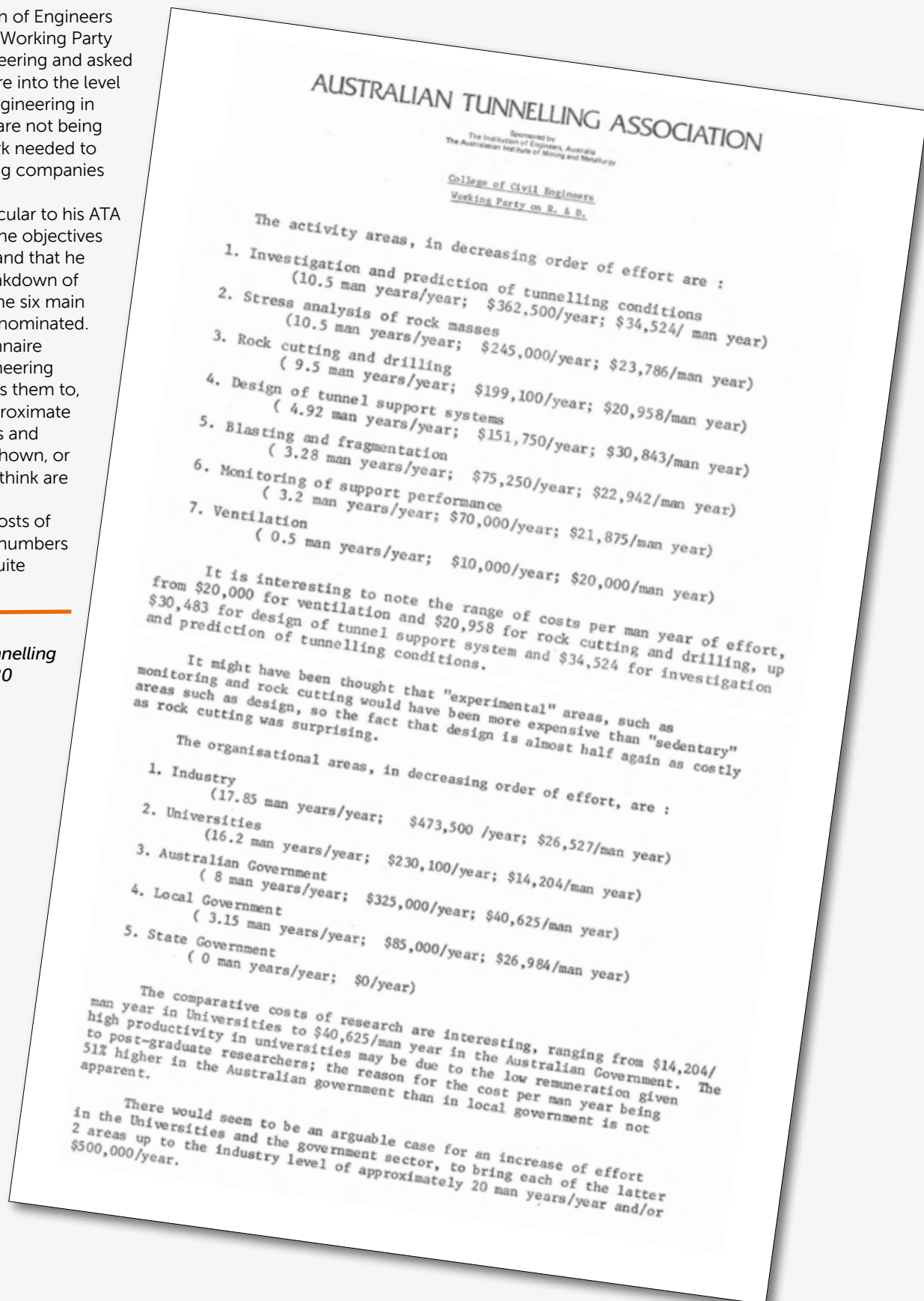
Bill Bamford is tasked with finding out what is not yet being studied but should be studied in order to progress the tunnelling industry in Australia.

In 1979, the Institution of Engineers Australia appointed a Working Party on R&D in Civil Engineering and asked Bill Bamford "to inquire into the level of research in Civil Engineering in Australia; what areas are not being studied and what work needed to be undertaken" among companies working in tunnelling.

Bill duly wrote a circular to his ATA colleagues detailing the objectives of the working party and that he has "attempted a breakdown of tunnelling R&D into the six main activity areas" he has nominated. He sends his questionnaire to group of civil engineering organisations and asks them to, "please supply an approximate estimate of man years and dollars for the areas shown, or for others which you think are appropriate."

Compared to the costs of tunnelling today, the numbers Bill gets back seem quite quaint today.

Source: Bamford Tunnelling R&D Report April 1980





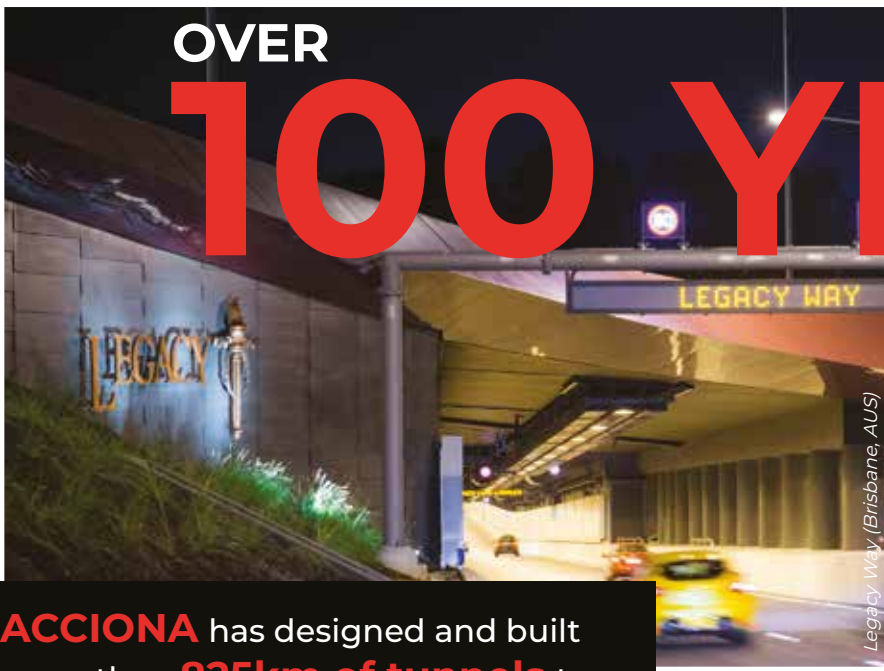
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BUSINESS AS **UN**USUAL

Neyland and Bennet... Classic tunnelling paper review

ATS President Harry Asche reviews the 1974 classic tunnelling paper presented at the Re-Shaping Cities Using Underground Construction conference: Pilot Tunnel Investigations into Aspects of Excavation and Primary Support for Melbourne Underground Rail Loop Tunnels by Neyland and Bennet.

The context

In 1974, the Melbourne Underground Rail Loop (MURL) was Australia's next big tunnelling project, following Snowy Hydro and the Eastern Suburbs Rail Line in Sydney. Snowy Hydro had involved a research group that included famous names, such as John Jaeger and Tom Lang, and pioneered rock bolting and rock mechanics. The Eastern Suburbs line included an early TBM drive in Sydney Sandstone and also included multiple drift methods for station construction (Trinocular? Try Pentanocular!).

The paper presented by Neyland and Bennet is therefore very important, and as it is now 48 years old, worthy of some commentary.

The authors

Allen Neyland

As ATS members know, the Allen Neyland Tunnelling Achievement Award recognises outstanding contribution to the Australian tunnelling and underground construction industry. The award was named after Allen in 1993 following his untimely death, in recognition of his service to ATS and the industry.

Allen's tunnelling career began in the Snowy Mountains Scheme following graduation from the University of Melbourne in civil engineering. He then worked with the H.E.C. at Poatina in Tasmania, a project which introduced the first Robbins TBM to Australia. He subsequently moved to the Melbourne and Metropolitan Board of Works and was associated with the pioneering development of the well-known "Melbourne Head" to overcome stability problems in broken ground.

Pilot Tunnel Investigations into Aspects of Excavation and Primary Support for Melbourne Underground Rail Loop Tunnels

by

A. J. NEYLAND, B.C.E., M.I.E.Aust.

Senior Resident Engineer, John Connell – Mott, Hay & Anderson, Hatch, Jacobs, Melbourne and

A. G. BENNET, B.E., M.Eng.Sc., Ph.D., Grad.I.E.Aust.

Geomechanics Engineer, John Connell – Mott, Hay & Anderson, Hatch, Jacobs, Melbourne

SUMMARY. Two pilot tunnels were constructed for the Melbourne Underground Rail Loop to assess behaviour of primary support, construction methods and provide exposures for future tenderers. The Adderley Street pilot tunnel was a small drift driven through basalts, sandy clays and into weathered Silurian mudstones, whilst the Treasury Gardens pilot tunnel was a full size section of running tunnel constructed in Silurian strata. Together, these structures enabled assessment of rib, rock bolt, and shotcrete support systems, particularly in regard to ground settlement problems.

Results from extensometer and slope-meter installations showed the effectiveness of a shotcrete skin in conjunction with ribs or rock bolts in developing a rock arch and limiting ground movement over the tunnels to a very few millimetres for most circumstances. Other results obtained included information on rock modulus and blasting vibration characteristics. Construction techniques including shotcrete ground support and excavation by a small tunnelling machine were assessed. The results from the pilot tunnel investigations were then further tested in a small preparatory contract before committing major works with the shotcrete-rib method.

"From a personal point of view, Allen Neyland was my first boss, who I found to be kind and patient as well as practical and knowledgeable. I then worked with Sandy for many years and owe him a debt of gratitude for his support and advice when working on my own PhD." Harry Asche, ATS President

Sandy Bennet

Sandy Bennet had a PhD in the then very new application of finite element analysis in geomechanics, and he was a specialist in ground engineering when he joined the MURL project. Sandy continued his career in tunnelling and geomechanics through assignments in Australia, Asia and the Pacific in a 32-year career with the Connell Group (now Aurecon) and continues to work in the field with Flagstaff Consulting. His introduction to the MMBW South Eastern Trunk Sewer Project in his PhD studies was the foundation of a long personal and professional association with Allen Neyland and Frank Watson for the duration of the MURL design and construction phase and subsequent development of criteria for assessment of future development adjacent to the Loop structures, and the significant redevelopment of Spring and La Trobe Streets that followed completion of MURL.

The paper

Melbourne's geology being more variable than Sydney's led to the concept of Pilot Tunnel trials early in MURL's construction with the hope that the information could be used to create a toolbox of methods for the main works. Some of

these methods were, at that time, quite new in Melbourne, including the use of a roadheader machine, and the use of support consisting of rockbolts, shotcrete and steel sets. The Pilot Tunnels were also used to further the knowledge of Melbourne's Silurian formation, categorised as Classes Z1 to Z5, and to measure some of its properties. Blasting trials were also carried out to confirm "site laws" for the project.

An interesting result was the recommendation of a shotcrete skin, followed by installation of steel sets to provide effective and stiff support. I believe that the use of steel sets provides the best way of avoiding settlement in weak rock, but this method has fallen out of favour in Australia.

The paper also points out that the pilot tunnel trials cost less than 1% of the total project cost, and yet provided vital information. Again, the use of pilot tunnels has fallen out of favour in Australia, yet this technique can save money in the long term.

You can read this paper in full on p.15 of the Re-Shaping Cities Using Underground Construction conference paper here: www.ats.org.au/wp-content/uploads/2022/02/1974_Melbourne_Reshaping_Cities.pdf

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The great benefit of conferences and events

As a technical society, one of the key reasons the ATS exists is to distribute timely information about cutting-edge innovations and techniques to its members. It's an important forum for tunnelling professionals and enthusiasts to participate in professional technical development, and the ATS runs high quality continued professional development (CPD) related to all tunnelling topics.

Each of the state chapters is responsible for its own program of technical sessions which, depending on the state and subject matter, are run between monthly and twice yearly. These technical sessions can be run by individuals with something important to share, researchers, corporate sponsors or representatives from the major suppliers in the tunnelling industry wanting to promote a new piece of technology. Pre-pandemic, technical sessions used to be just face-to-face, attracting only local members, but now they are generally offered as hybrid (face-to-face and online), which means attendance rates have skyrocketed from between 20-100

attendees (depending on the state) to up to 500+ per session.

In addition to technical sessions, the state chapters run ad hoc workshops and take it in turns to organise the multi-day ATS Short Course in Tunnel Design and Construction every two to three years. The importance of this course as an insight to tunnelling cannot be overestimated because it is often a student, graduate, or early-career engineer's first glimpse of what a career in tunnelling actually looks like. This is because the topic is not generally covered or promoted in undergraduate civil engineering degrees in any of the major universities in Australia. In many cases, the ATS Short Course has been the prompt that results in a career switch away from building high-rises and bridges into exploring the underground.

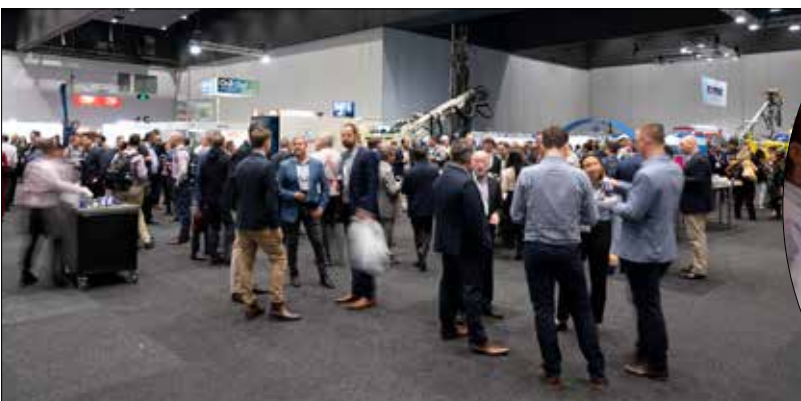
Then there is the highlight event in every tunneller's calendar - the triannual Australian Tunnelling Conference - partly for networking, partly for learning something new, partly to find out what industry and suppliers are working on, but also to see everybody together in

a social and relaxed environment. Conference organisation is generally shared between Sydney, Melbourne and Brisbane, but Auckland has hosted one too. To date, there have been 17 Australian/Australasian Tunnelling Conferences with two of them holding the additional honour of being held in conjunction with the World Tunnelling Congress (in 1987 in Melbourne and 2002 in Sydney).

Aside from the professional development opportunities, one of the most valuable benefits of ATS events is the opportunity to network with like-minded professionals, to trade tales and build connections that end up going as deep as some of the projects they work on. Tunnelling in Australia is a relatively small world, so connections can often last decades and transform into enduring friendships. This perhaps is not all that surprising in a career where people face genuine risks as they head underground. Having the sense that your colleagues 'have your back' is not taken for granted, it can also save your life.



ATS 2022 Short Course with Tom Roper, Keith Bannerman and Jurij Kartovsek



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Q&A with Alan Robertson

Alan Robertson has been a member of the ATS for over 35 years, which complements his almost 50 years of experience in the mining, quarrying and tunnelling industries. He held the role of ATS Queensland Chapter Chair between 1988 and 2000, and was the ATS National Executive President between 1999 and 2000. His passion for supporting young ATS members is first class and his mentoring has no doubt helped countless young workers excel in the tunnelling industry. Alan organised and supported numerous ATS events including conferences, short courses and workshops and, through his vast industry network, introduced many sponsors to the ATS, many of whom continue to support the Society.



My first experience with mining and tunnelling was a gap year whilst studying engineering at the University of Queensland back in the early 1970's. After a difficult second year of studies, I headed off in my Morris Major from Brisbane to Queenstown on the west coast of Tasmania to complete underground vacation experience at the Mt Lyell Mining and Railway Company. The change in my environment had a major impact on me and I ended up staying a full year. When I re-joined my studies, with the experience gained, I cruised through the rest of my mining degree.

On graduation, I worked at Mt Isa and then, with my new wife Adele and small son Aidan, headed back to work in Tasmania. Then, with an added family of two daughters, we headed to Marble Bar Western Australia, then Queensland, and finally Brisbane where I joined Tennent Isokangas Pty Ltd Consulting Mining Engineers as a Director. By this point it was the late 1980's and the start of my interest in tunnelling and the ATS (or AUCTA as it was then called).

Can you describe the development of the ATS in Brisbane?

When I first joined, Brisbane tunnel and underground projects in progress included the City to Roma St and City to Fortitude Valley Rail Tunnels, and the South-East Busway, and there was great energy among Brisbane's tunnelling stalwarts, including Harry Asche, Andrew Day, Warren Mahoney and others.

Our early meetings were held at the Engineers Australia (EA) office in Upper Edward St with attendees including students from the University of Queensland and the University of Technology (then QIT). The catering

was often provided free of charge by my daughters Jasmine and Claire. I completed a Masters Degree in Environmental Management with a focus on underground space development as well as working as a lecturer/tutor at the University of Queensland.

The ATS continued to grow throughout the 1990's as we started to hold underground space workshops and Brisbane was identified, on both national and international scales, as being a highly suitable place for underground space development and tunnelling. The North South Bypass Tunnel (Clem 7) and TransApex projects demonstrated this well.

This continued through the 2000s and by the 2010s, Brisbane had even become Australia's "tunnel town," stealing the trophy from Sydney and Melbourne for a short time during the completion of the Inner Northern Busway and "back-to-back" Airport Link Tunnel and Legacy Way Tunnel. As a Consulting Mining Engineer, I was

"The ATS has always been on the cutting edge of what goes on with tunnelling. They've never lagged behind and that's a fantastic achievement."

involved with the concept design and implementation of the innovative waste dumping of the Legacy Way tunnel boring machine (TBM) spoil into the operating Mt Coot-tha Quarry.

It has been a real pleasure to see the Brisbane ATS Chapter go from strength to strength as each new wave of engineers and industry representatives become involved. These days this includes the Young Members and Diversity in Tunnelling Sub Groups, and our technical sessions continue to attract some of the largest audiences of all the EA Technical Societies. I remained active on the Brisbane ATS Committee, organising Underground Space Workshops and Tunnel Open Days at Mt Coot-tha Quarry until the end of 2021 when I retired.

What has your involvement with the ATS meant to you personally?

I've made lifelong friends with lovely people of similar interests. That's been the main outcome. But I've also been able to talk freely about my passion, which is the better utilisation of the underground.

Can you describe this vision in more detail?

My vision is that we better use the available space in our cities by going underground, particularly where the rock types and surface topography are amenable, for example in major cities like Brisbane.

I think there are lots of opportunities to replace certain aboveground structures (such as carparks and transportation networks) with infrastructure like parklands to make life for people more pleasant. I think many types of commercial activities could go

underground too. About 25 years ago I presented an alternative to a Bunnings hardware store, with the same basic design just in an underground structure. Once inside a place like Bunnings, you wouldn't know (or care) whether you were underground or not, so why not use that precious above ground space for something else? I believe facilities like water storage and many other types of public utilities can also be located underground. I've written several papers on this topic.

What are you most proud of in terms of your contribution to the ATS?

My proudest moments come about when I see what our young engineers are capable of, particularly, but not always, the ones I've mentored or helped train. This new wave of engineers and related professions are incredibly interesting and intelligent people. When I see these young engineers succeed and know they'll take the tunnelling industry into new and interesting areas I just feel great.

How would you summarise the main achievements of the ATS in the last 50 years?

The ATS has always been on the cutting edge of what goes on with tunnelling. They've never lagged behind and that's a fantastic achievement.

The ATS has also always encouraged improvement within people that work in the tunnelling industry as well as encouraging others to join. Through courses, training sessions and

conferences of a very high quality, the society continues to attract tunnellers from all over the world, and it's also great now to see an emerging focus on diversity.

Underground Space Workshops

As a volunteer society, that exists purely because of the passion of its members, if an ATS member has an idea they'd like to pursue, they can pitch it to their chapter committees or National Executive Committee and, if it gets the nod, the infrastructure is in place to help them achieve it. A good example of this are Alan Robertson's Underground Space Workshops that he championed and organised alongside colleagues of the Queensland Chapter over a period of two decades. Held in 1995, 1998, 2006 and 2013, these well attended, much hailed workshops inspired participants to deeply consider the need and opportunities for underground space in Brisbane in the decades to come.



**The President,
Australian Tunnelling Society**

Dear Harry,

Warmest congratulations on reaching the half century mark!

Fifty years of being a continuous voice for all things underground is no small achievement. Your society has long had a reputation for diligence in advancing the development of underground space and perhaps especially for investment in emerging young professionals.

It is therefore a pleasure to extend well wishes from New Zealand for your achievement and to wish you on-going success in the years ahead.

We are very much aware that the current New Zealand Tunnelling Society owes its strength to small beginnings as a chapter of the ATS, albeit then the Australasian Tunnelling Society – a testament to the good heart of the society in reaching out to all who are involved in tunnels and tunnelling.

With kind regards,

**Matt Mules
Chair, New Zealand Tunnelling Society**



A very modern tunneller

Keith Bannerman is the Tunnel Manager for Bamser, a consulting firm who specialise in tunnelling works and major engagements across most infrastructure scale tunnel projects. He has held roles on ATS committees since 2013, including as the ATS Young Members (ATSym) National Representative between 2017 and 2020. He has also represented Australia on the world stage as the Chair of the Young Members Group of the International Tunnelling Association (ITA) between 2017 and 2021. Now he has graduated from the junior ranks, he has become the Vice Chair of the NSW Committee.

How did I get into tunnelling? It's funny, the more I talk to colleagues, the more I hear a similar story to mine, which is that I accidentally fell into it. In 2007, during my undergraduate degree, I was offered a ticket to the ATS three-day intensive tunnelling 101 course in Brisbane. I went along, heard from genuine rock star tunnellers including Harry Asche (now President of the ATS) and Arnold Dix (now President of the ITA) about their passion for the industry and was so intrigued I got a summer job with a company who were building a 450m long shallow cover tunnel. From my very first day on the job, it was clear that tunnelling was, for me at least, more interesting than the traditional structural engineering disciplines. To learn more, I went along to the 2008 Australasian Tunnelling Conference.

I graduated in 2008 at about the same time my first daughter was born, and my wife and I decided that the long hours underground weren't a good fit for a new dad, so I initially became a designer. But 18 months later, the tunnelling bug had not gone away and I got my first underground role in Brisbane, working on



the Airport Link, which was the making of me as a tunneller.

I got more involved in the ATS as soon as I started this role and it has been a big part of my life ever since. The networking and knowledge

exchange opportunities are significant because many of the things tunnellers do are not actually written down in textbooks. Some of the best lessons I've learned are from talking with my peers at ATS events and meetings. That's why the Society has a growing focus on connecting senior engineers with junior engineers. Not only is that a great way to encourage more people into the booming industry, but sharing stories and experiences is a much more engaging way to learn some things that, even if they are written in a textbook, don't necessarily leap off the page.

There are three things I'm proud of so far in my contribution to not just the ATS, but the profession as a whole. First, the ATS Tunnel Design Guideline which I helped champion and which was published while I was chairing the ATSym group. Simon Brinkman took the lead on that and did a fantastic job. The second was my contribution to the ATS Air Quality Working Group, which won the Health and Safety Award at the ITA Awards in Miami in 2019 for an Outstanding Health and Safety Initiative. The third was helping to establish World Tunnel Day - 4 December - on the ITA calendar.

I've enjoyed all my projects but, as I said, the Brisbane Airport Link was the making of me as a tunneller. It was a turnkey project which we had to do in a very short timeframe while incorporating the use of practically every single technology you could possibly think of. The complexity was intense, but I enjoyed not necessarily knowing exactly what was going to happen in a month's time. I also love that now, when we drive through it, the kids always say, "This is the tunnel that daddy built!"

Talking of the kids, balancing the commitment to a mega project and



Airport Link - Rose St Caverns with TBM Breakthrough (2011)

"I'm committed to continuing to work both within the ATS while keeping strong connections to the ITA and helping both in their missions to strengthen how they articulate the role of the underground in mitigating the challenges we face, particularly as regards climate change."

commitment to a family is an ongoing struggle for people who work in all areas of engineering and construction. Airport Link was particularly challenging as regards this because I was effectively earning my stripes as a tunnelling engineer and, as a result, working incredibly long hours. I got married and had another child during that project and only took a week off for each. It was hard for my wife and I, as a partnership, but it did help me re-evaluate what I wanted out of a career and I've carefully chosen roles since that allow me to both enjoy my job and enjoy my family. Advocating for positive change in this area will be one of the focus areas of the ATS Diversity in Tunnelling Sub Group, and I'm very supportive of it because unfortunately in our industry, we do see a lot of people with relationships that go through turmoil.

As for the future, I'm committed to continuing to work both within the ATS while keeping strong connections to the ITA and helping both in their missions to strengthen how they articulate the role of the underground



ITAYM Steering Committee at WTC2019 incl. Sandeep (India), Giuseppe (Italy), Keith (Australia), Jasmin (Switzerland), Jekaterina (Sweden), Chrysothemis (Greece), Sindre (Norway)

in mitigating the global challenges we face, particularly as regards climate change. I'm also committed to my other passion which is to help foster and develop the talents and knowledge

of up-and-coming young engineers. These are the people who will become the leaders of our industry into the future so it is vital to support that essential knowledge exchange."

St Barbara and World Tunnelling Day

The story of St Barbara - the Patron Saint of Tunnellers

St Barbara is thought to have been born in the mid-third century close to present-day Lebanon. Legend has it that her father, when he learned she had converted to Christianity, had her tortured and eventually beheaded. Her martyrdom took place on the 4 December and as punishment for her murder, her father was struck by lightning and killed. It is this legendary association with lightning that gives Saint Barbara her contemporary connection to explosives and the tunnelling and mining professions.

Today, the legend still inspires tunnellers. In honour of St Barbara, every single TBM is given a traditional female name before use, and it is common, particularly in Catholic countries, for a small statue and shrine to St Barbara to be erected at the tunnel entrance. In Australia, the tradition is still alive and well.

"I was at the West Gate Tunnel in March 2022, Australia's largest and most recent tunnel, and there, in front of this huge TBM called Bella (after Bella Guerin, the first woman to graduate from a university in Australia in 1883), there is a small statue of St Barbara. The tradition is very real and many tunnellers won't proceed unless there is a St Barbara ceremony to initiate the tunnel."

Charles MacDonald, ATS National Executive Committee Member

ATS takes the lead to make St Barbara's Day more inclusive

While St Barbara's Day has been celebrated for centuries in Europe, in 2018 a movement began within the newly formed ITA Young Members Group, championed by the ATS's Jurij Karlovšek and Keith Bannerman to celebrate St Barbara's Day in a format that was more inclusive. The resulting World Tunnel Day is now held in the first week of December to coincide with the Feast Day of Saint Barbara. The goal is to generate interest in world class tunnelling projects and to promote the industry by holding celebratory events and posting photos, video clips and messages on social media using #WorldTunnelDay.



"We were interested in making this day appeal to a secular audience and people from other religions and cultures. Now in its fourth year #WorldTunnelDay has been a really successful way to connect across borders and celebrate all tunnellers' passion for the underground."
Keith Bannerman, Vice Chair of ATS's NSW Chapter and immediate Past President of the ITAYM

Our friends in industry

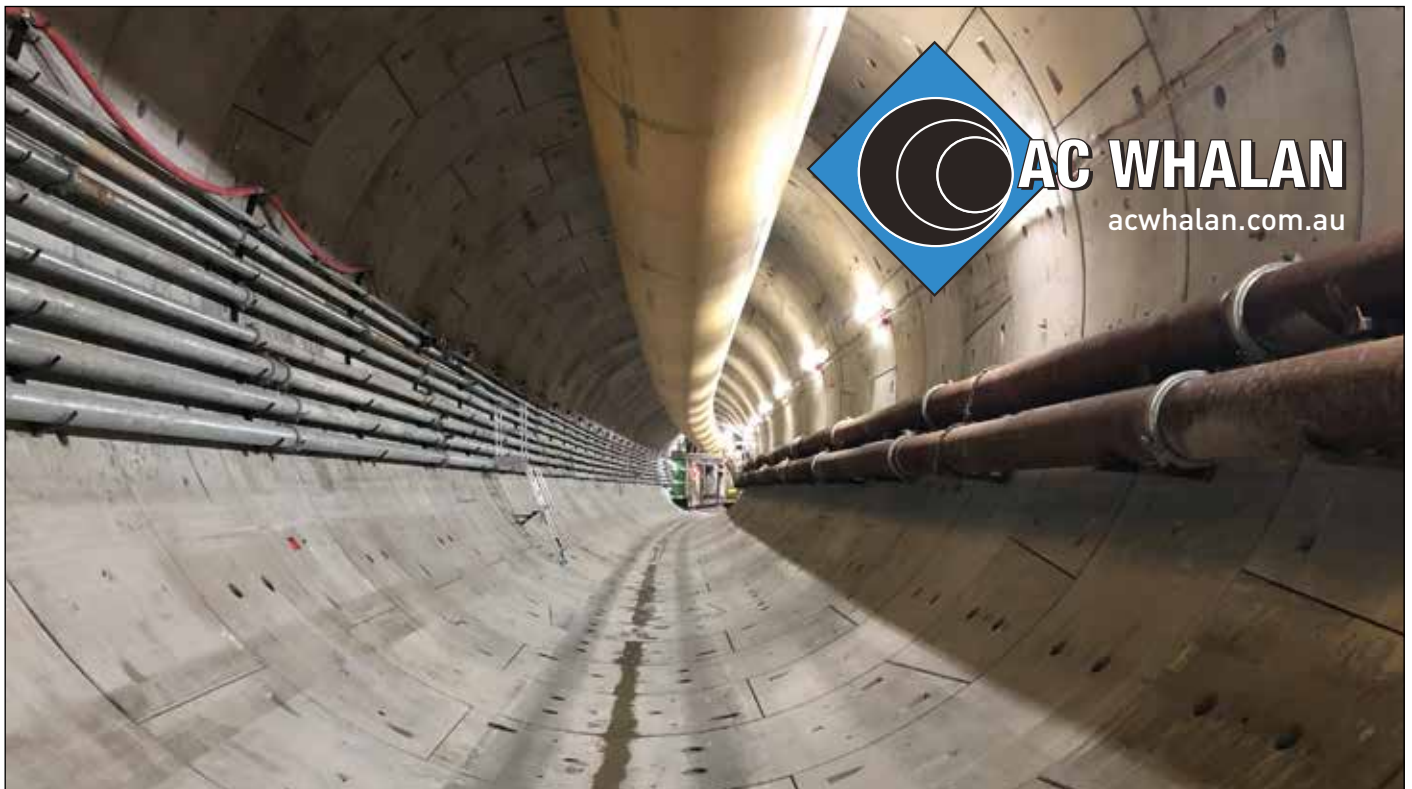
The ATS has the most positive impact on our members and the wider industry through running regular technical sessions, events and conferences, which not only educate and enlighten, but also bring the tunnelling community together. Events that offer members the face-to-face opportunity to mingle with professionals from different tunnelling disciplines can have a positive and far-reaching cross-pollination

impact on research and construction projects, companies and the disciplines themselves.

This, in addition to our members volunteering their time to sit on working groups to write, update and improve codes and standards nationally and internationally, has won us many friends in industry, many of whom have seen the value of financially supporting our work.

Since the very first time we opened

our doors to sponsors in the year 2000 (when the first to sign up included Atlas Copco Construction, Ove Arup & Partners, Peabody Resources, Thiess Contractors, Terratec Asia Pacific, Transfield, Castrol Australia, Onesteel Reinforcing, Walter Construction Group and Xypex Australia), our industry partners have been very supportive. There is no question their help has enabled the ATS to thrive.



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Short Q&As with five ATS sponsors

Today, we have six Platinum sponsors and 45 Gold corporate members and here we will hear from just a few of them about why they decided to invest their trust in us. But before we get to that, our key message to all our sponsors, is one of Huge Thanks. We couldn't do what we do without you.

Platinum Sponsor - John Holland

JOHN HOLLAND



David Hake is the General Manager of Tunnelling at John Holland who were an inaugural Platinum Sponsor of the ATS and have supported it with sponsorship and staff involvement ever since.

Why have you been such a stalwart supporter of the ATS?

The ATS has provided a solid platform for developing tunnelling professionals in Australia over the past 50 years through technical sessions, short courses and conferences. These events have been run efficiently and have delivered profitable outcomes to the ATS, which has enabled the ATS to continue to support the tunnelling industry. We see the value that the ATS has added to the industry and, particularly, the development of our own tunnelling professionals.

How long has your company been involved in tunnelling and what are your key offerings?

John Holland has been constructing tunnels in Australia since 1966, with the commencement of the South Eastern Trunk Sewer in Melbourne followed by the Talbingo Dam Diversion Tunnel for the Snowy Mountains Hydroelectric Scheme in 1967. We have been involved in both hard and soft ground tunnelling throughout Australia since this time. Initially, our focus was the construction of tunnels for the water and wastewater sectors, but we now find most of our tunnelling revenue comes from the transport sector. Throughout this long history, there is a pattern of projects delivered to suit the growing needs of cities, from utility infrastructure tunnels to transport infrastructure tunnels in the major cities.

Why do you like the business of tunnelling?

Underground infrastructure in Australia enhances the lives of Australians and offers tunnelling professionals the opportunity to work on iconic projects that are challenging, meaningful and rewarding. It provides our clients and our people the opportunity to stand back with pride and say, "we did that." The challenges and achievements have helped to forge long term relationships and friendships (even friendly rivalries) in the industry, through mutual respect for the effort required to deliver these amazing projects.

How would you like to see the ATS evolve in the future?

We would like to see the ATS become a more recognised "voice of industry" in the public domain concerning the effective use of the underground for providing the public and private infrastructure necessary for improving our daily lives in Australia.

Platinum Sponsor - Bekaert



Brad Boardman is Area Sales Manager, South East Asia/ Oceania, for Bekaert, which has been involved in tunnelling in Oceania for over 20 years. Bosfa Pty Ltd (a fully owned subsidiary of Bekaert), has been an ATS Platinum Sponsor for the last eight years.

Why have you been such a stalwart supporter of the ATS?

We believe it's important to actively give back to the market that supports our business and supporting the activities of the ATS is a great way to do this. We believe it to be imperative that all those involved in the tunnelling industry have a voice. Being a Platinum Sponsor allows our team to educate the industry and learn from and understand the industry better, as well as receive great networking opportunities.

How long has your company been involved in tunnelling and what are your key offerings?

Bekaert has been involved in tunnelling globally since the 1980's. As Oceania's largest supplier of engineered concrete fibre reinforcement solutions, we've gone from offering a single fibre type to offering a number of fibres (whether it be different geometry, strength, material type or even how they are collated), to allow better dispersion within the concrete mix. We've made our most significant changes after listening to what the market wants and then investing significantly in creating it.

Why do you like the business of tunnelling?

From a suppliers' perspective, it's great that the materials required to build a tunnel in Australia are selected strictly on a performance basis with ongoing product quality assurance and quality control during any project being imperative. This means inferior products, no matter how cheap, will not be accepted.

How would you like to see the ATS evolve in the future?

First of all, I'd like to congratulate all members of the ATS, past and present, for reaching 50! It's a momentous milestone. It gives me great pleasure to see the ATS swell in numbers with such a diverse range of people and backgrounds. I think they do a great job, particularly as a volunteer organisation, but I would love to see greater communication between chapter committees to make sure successful ideas, plans and processes are pollinated across the whole organisation.

Platinum Sponsor - Bamser



Keith Bannerman is the Manager of Tunnels at Bamser, who have supported ATS local chapters and the National Committee since its inception in 2008.

Why have you been such a stalwart supporter of the ATS?

The ATS is the peak organisation for tunnelling locally and brings together a diverse group of professionals. By actively supporting the local chapters our employees are provided an excellent opportunity to contribute to the industry whilst networking with other leading industry professionals. By being part of the ATS we are also able to drive industry initiatives such as the recent ATS Air Quality Working Group, Code of Practice development and Tunnelling Design Guideline to help drive positive change within the market sector. We are incredibly proud to be a Platinum Sponsor. We congratulate the ATS on this substantial milestone and look forward to being part of the next 50 years.

How long has your company been involved in tunnelling and what are your key offerings?

Tunnelling has been Bamser's core service since it was founded by three mining engineers in 2008. Since then, there has been an increase in the sophistication and complexity of tunnelling projects and schemes being developed. The WestConnex program of works in Sydney, TransApex projects in Brisbane and North East Link are all multi-billion-dollar mega projects which have dominated the industry's consciousness alongside significant rail projects such as the Sydney and Melbourne Metro projects.

Why do you like the business of tunnelling?

Tunnelling provides a technically challenging work environment with each project providing its own unique opportunities. It's true that two tunnels are never alike, and it is this variety which keeps our employees engaged and always looking to raise the bar.

How would you like to see the ATS evolve in the future?

The ATS provides fantastic representation of the industry but is facing a challenge where our membership doesn't reflect the sheer scale of tunnelling professionals working across the country. It would be excellent if the ATS could pool even more of this experience together to allow innovations and lessons learnt to permeate across the industry to drive a more efficient tunnelling sector.

Gold Corporate member - Mapei



After being established as a subsidiary of the global enterprise in 1993, Mapei Australia decided it was important to sponsor the ATS, as explained by Luke Foyster, Technical Engineer for Underground Technology.

Why have you been such a stalwart supporter of the ATS?

Our association with the ATS allows us to bring our expertise and knowledge of construction chemicals for underground works to a wider audience and there is a benefit to the ATS membership to be the first to know about cutting edge technology that suppliers are bringing to the market. We appreciate the support of the ATS, particularly noting that it is run by volunteers from the industry and thank them for the time and effort they put in to make it such a worthwhile organisation. Mapei

has supported a number of ATS initiatives including the St Barbara's Day dinner and technical sessions. The St Barbara's Day dinner is an important celebration where we get to bring tunnel professionals together outside of the project environment. This forum is an informal place to catch up with colleagues past and present and, in a small way, thank our customers.

How long has your company been involved in tunnelling and what are your key offerings?

Mapei has over 85 years of experience in the underground space involved in all manner of projects both big and small developing a project range to support the challenges of underground works through the design, construction and maintenance phase of underground assets. Our key products are backfill grout for segmental linings, rockbolt grout, waterproofing, macro synthetic fibres and shotcrete accelerators.

How would you like to see the ATS evolve in the future?

Regular face to face meetings are important together with seminars with good technical content. An annual gathering for practical demonstrations would also be very beneficial.

Gold Corporate member - Promat



Rick Fox is the Regional Tunnel Manager for Promat in the Asia Pacific Region which is involved in developing passive fire protection solutions for tunnels. Promat has been a Gold Sponsor of the ATS for over a decade.

Why have you been such a stalwart supporter of the ATS?

We support the ATS because it facilitates the coming together of the tunnelling community which is important

and vastly different to the normal construction industry.

How long has your company been involved in tunnelling and what are your key offerings?

Promat have been protecting tunnel structures from fire for more than 40 years throughout the world and provide certainty when protecting tunnels from fire, including the harsh RWS and HCM fire curves.

How would you like to see the ATS evolve in the future?

I would like to see the ATS continue to be the leading industry association linking the tunnelling community and facilitating standards reform. Promat would like to congratulate the ATS on 50 years, and may there be many more!

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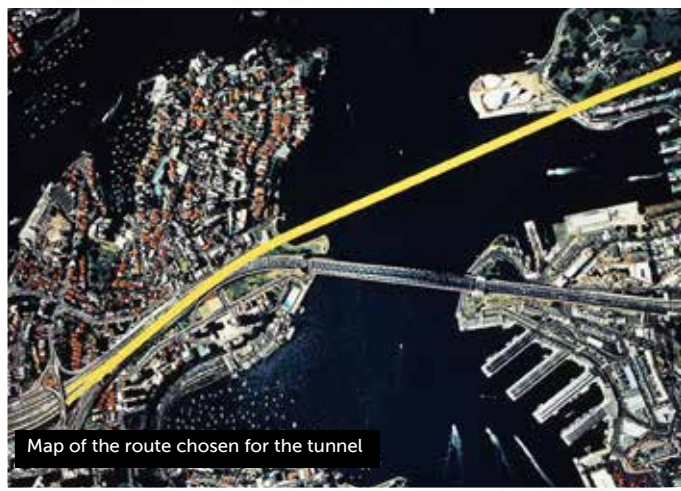
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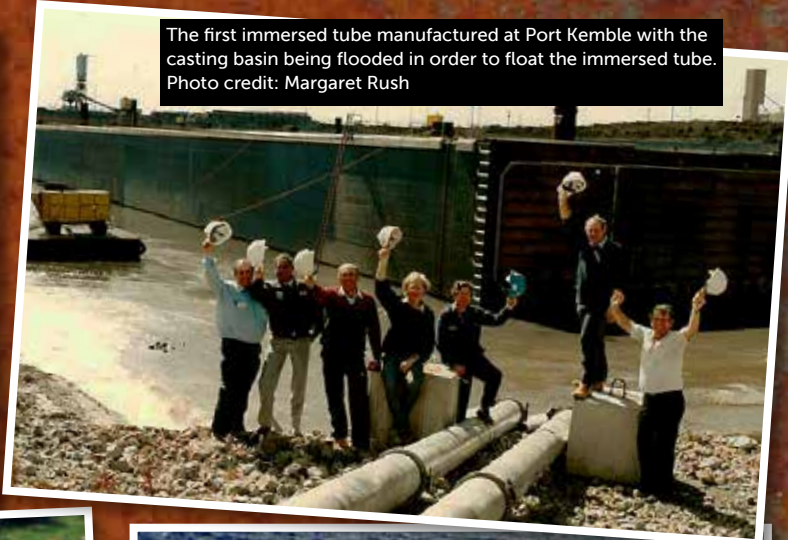


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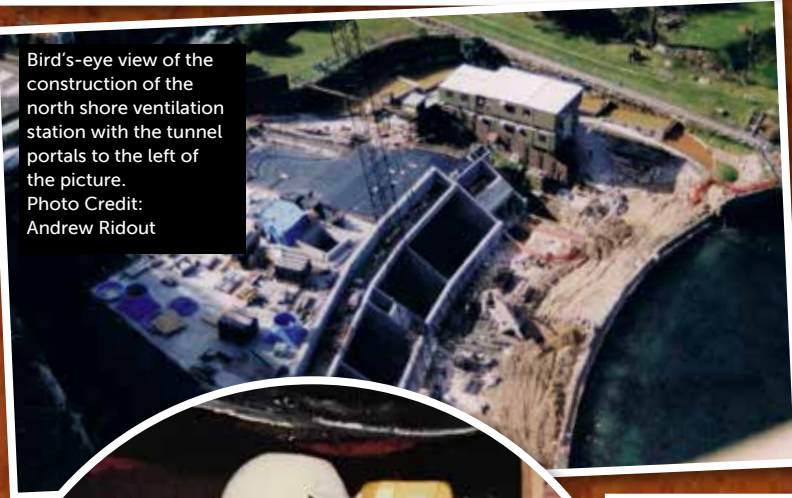
Sydney Harbour Tunnel



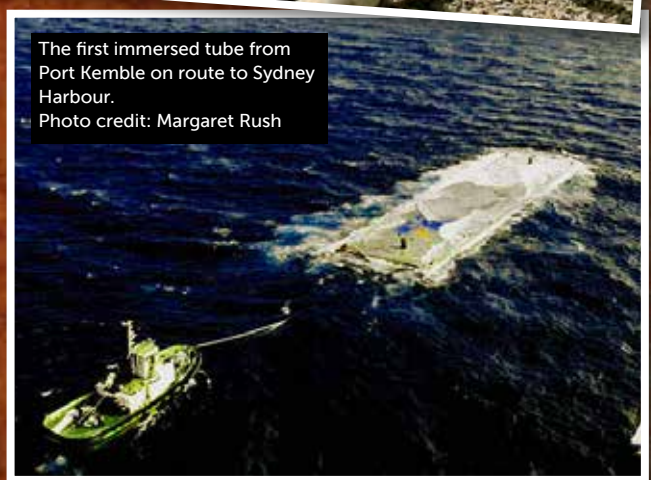
Map of the route chosen for the tunnel



The first immersed tube manufactured at Port Kemble with the casting basin being flooded in order to float the immersed tube. Photo credit: Margaret Rush



Bird's-eye view of the construction of the north shore ventilation station with the tunnel portals to the left of the picture. Photo Credit: Andrew Ridout



The first immersed tube from Port Kemble on route to Sydney Harbour. Photo credit: Margaret Rush



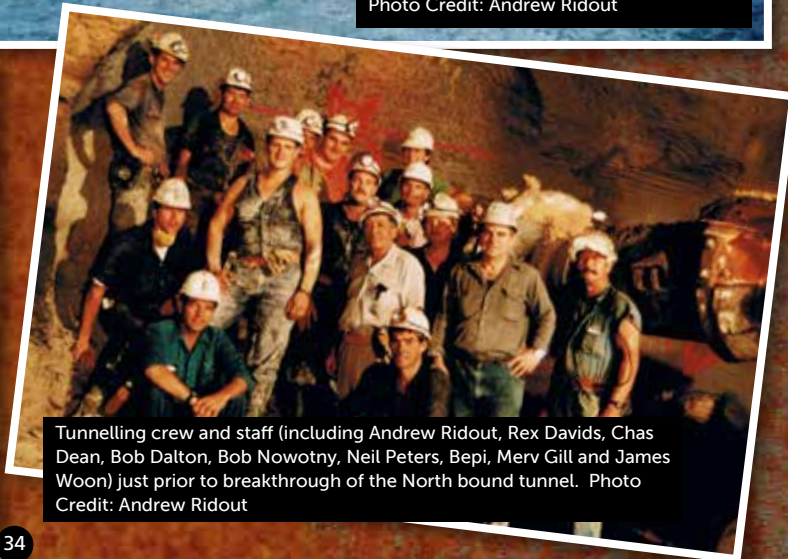
Franco Beljorno Nettes and Claudio di Berardino coming out of one of the first immersed tube units for the Sydney Harbour Tunnel. Photo credit: Margaret Rush



Tunnel portals situated near the ventilation station on the north shore. Photo Credit: Andrew Ridout

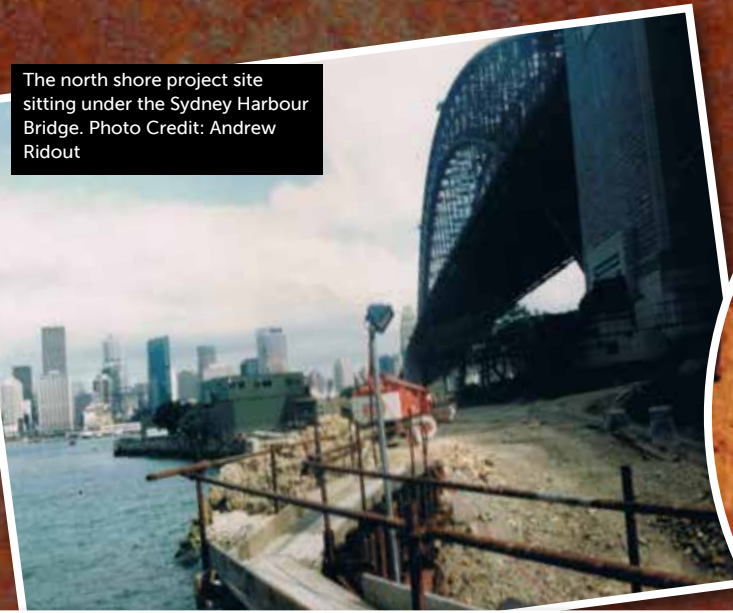


Excavation of the northbound tunnel by drill and blast after an initial bored pilot tunnel. Photo credit: Andrew Ridout

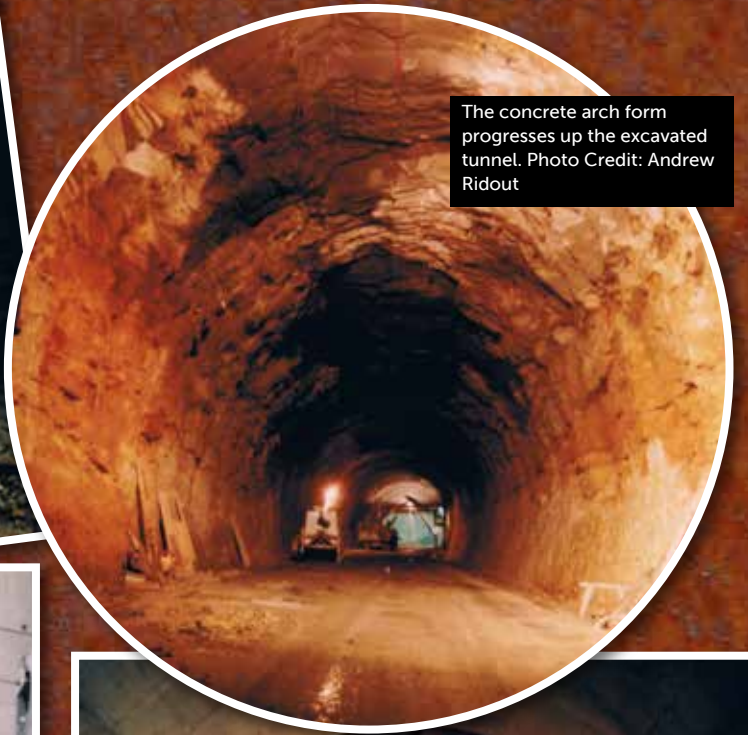


Tunnelling crew and staff (including Andrew Ridout, Rex Davids, Chas Dean, Bob Dalton, Bob Nowotny, Neil Peters, Bepi, Merv Gill and James Woon) just prior to breakthrough of the North bound tunnel. Photo Credit: Andrew Ridout

The north shore project site sitting under the Sydney Harbour Bridge. Photo Credit: Andrew Ridout



The concrete arch form progresses up the excavated tunnel. Photo Credit: Andrew Ridout



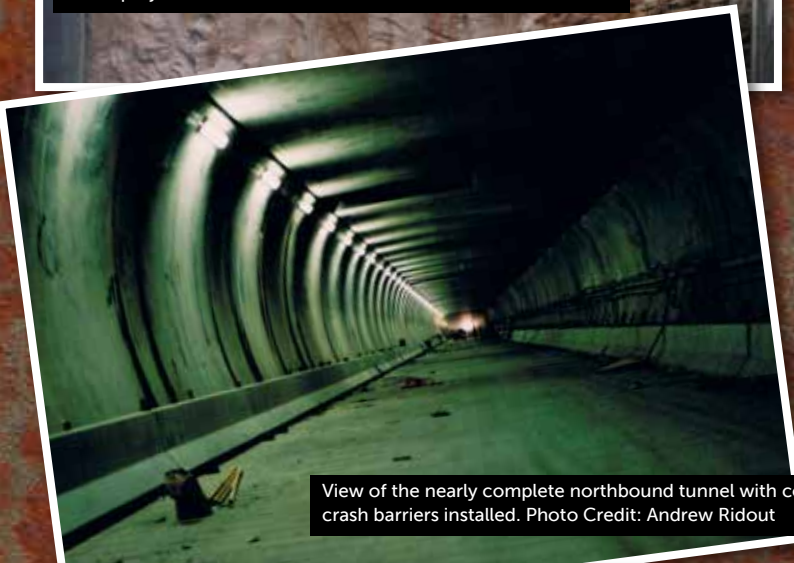
Breakthrough of the top heading into the cut and cover portion of the project on the north shore. Photo Credit: Andrew Ridout



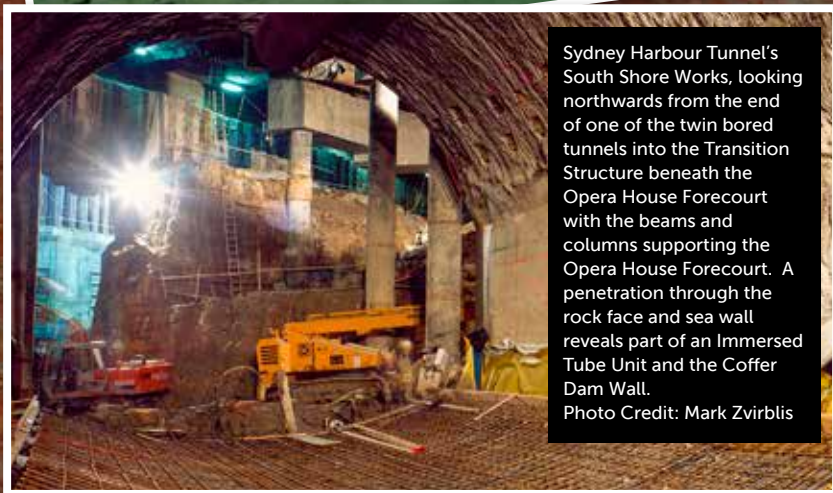
The travelling concrete formwork ahead of some of the lined tunnel. Photo Credit: Andrew Ridout



View of the nearly complete northbound tunnel with concrete crash barriers installed. Photo Credit: Andrew Ridout



Sydney Harbour Tunnel's South Shore Works, looking northwards from the end of one of the twin bored tunnels into the Transition Structure beneath the Opera House Forecourt with the beams and columns supporting the Opera House Forecourt. A penetration through the rock face and sea wall reveals part of an Immersed Tube Unit and the Cofferdam Wall. Photo Credit: Mark Zvirblis



"I started work with the Sydney Harbour Tunnel in May 1992 as a tunnel controller and was the opening controller at 03:00 31 August 1992. Ownership of the Sydney Harbour tunnel was passed to Transport for NSW (TfNSW) at midnight 31 August 2022 after 30 years of successful operations. It was a smooth transition with Ventia appointed as the operator and maintainer. It was my pleasure to be involved with the Sydney Harbour Tunnel and to be able to pass ownership to TfNSW 30 years later."

Bob Allen, Sydney Harbour Tunnel General Manager, 1992-2022

"An iconic tunnel under an iconic bridge, next to the iconic Opera House in an iconic city in one of the world's great nations. Congratulations to everyone - from the visionaries that had the dream, the designers, the builders, the operators and the maintainers. May the next 30 years be as safe and uneventful as the last!"

Professor Arnold Dix, ITA President

ATS Leadership

The ATS has been very fortunate throughout its 50-year history to have had an executive leadership team, and state leadership teams, whose different iterations have always seemed to have the good of the industry at its core. Leadership never seems to have been about individual glory, instead it has revolved around the concept of service.

How can we best serve our members and therefore the industry? How can we improve the quality of the profession for everyone? How can we make tunnelling safer? These are the central questions the National Executive Committee and each state committee have always sought to answer with the activities they organise.

Some ATS Chairs have stepped forward willingly, some

took the role out of a sense of duty, and some have been strenuously encouraged to step into it by their colleagues, but all have taken the role seriously, adding their unique style to the evolving flavour of the organisation. Of course, there have been disagreements and robust discussions, but that sense of service has overridden it all and kept the Society focused on its overarching aims.

For this journal, we've been lucky enough to catch up with quite a few past ATS Chairs. We have already heard from founding chair Bill Bamford (Chair between 1975-1978), right at the start. We have also heard from Alan Robertson (Chair between 1999-2000). But in this section, we'll hear from many of the others, starting with the current ATS Chair, Harry Asche.

Establishing a firm footing for the next 50 years

A self-confessed "tunnel nut," Harry has over 40 years' experience in heavy civil engineering, rail, and tunnels. He is highly regarded within these industries and has won several prestigious industry awards and accolades. In 2018, these included being awarded the Engineers Australia Professional Engineer of the Year Award (Queensland Division) and winning the Roads Australia Award for Technical Excellence. He currently works as Design Director – Tunnels for Aurecon, playing an integral role in the firm's most technically complex projects including West Gate Tunnel in Melbourne and WestConnex in Sydney. Harry has been the ATS President since 2019.



Harry Asche helps with the clean up after a shotcreting research project at UQ

"I got involved in tunnelling because I like the fact there are no right answers and you're in a constant problem-solving state. I started my career as a bridge engineer, but I soon found it very restrictive. I was always referring to some clause in some code, I was becoming a technician. In tunnelling, there are no codes because the ground is complex and often unknown in its behaviour. You rely on the ground to create a tunnel. What happens if it behaves differently? Dealing with that uncertainty is a challenge I find so rewarding.

One of my first and most memorable projects was working on the Channel Tunnel in the UK. It was a fascinating project because the idea had been around for over 100 years. A French geologist had determined the probable route of the tunnel in the 1860s, and that was the route it ultimately took. There are not many projects that have over a hundred years of investigation before you start building them.

When I came back to Australia, I got involved in tunnel projects and joined the ATS in the early 1990s. While I had

spent my time at the Channel Tunnel getting to understand the basics of tunnelling, my earliest projects in Australia involved shallow tunnels in weak rock. In these projects, the key issue was controlling settlement and impacts to the surface infrastructure. This became the topic of my PhD, but the key message I would give is that if you want to have strong control over settlement, your support should contain a lot of steel, properly connected to the ground, and founded on something solid. In the 1990s, this allowed us to

build twin track or twin bus lane tunnels with less than three metres cover, and with very little movement.

A bit later, I started to get involved in the hydrogeology of the tunnel projects I was designing, initially feeling that this was an unwelcome distraction. It turns out that this topic is very interesting. Like tunnellers, hydrogeologists deal with significant uncertainty, and they have developed their own techniques, and indeed have created a science for dealing with uncertainty in groundwater behaviour. Part of my PhD involved using their techniques in tunnelling design, and I have now become involved in the groundwater assessment of many projects, enabling me to combine the two disciplines.

I was never ambitious in the ATS and became the Chair of the Queensland Chapter pretty much by accident. But then I ended up working closely with immediate past president Ed Taylor, who encouraged (read pushed) me to take the next step to being the ATS President. I've now been in this role for two and a half years and will serve one and a half more before passing the mantle on.

Working with Ed was truly wonderful. His focus was on making the ATS more strategic and during my transition to President, we put it all down on paper as a proper ATS Strategic Plan. Both of us wanted to do more for our members than we'd been doing previously and have gradually been making progress.

The ATS has now expanded beyond our traditional monthly meetings with a speaker, a national conference every three years and the occasional short course into many diverse activities. It

feels like there is great momentum, with the establishment of the Tunnel Systems Sub Group, Diversity in Tunnelling Sub Group, Young Members and more.

I am particularly proud of the efforts of the Diversity in Tunnelling Sub Group. They have written and published a Diversity and Inclusion Protocol with quotas for representation, such as a minimum 25% female representation of speakers at ATS events and increasing female representation on the National Executive to a minimum of 25% by 2024. It is my personal experience that engineering is a team sport, and a team that is diverse moves forward much more effectively because it has multiple perspectives and possibilities.

Another important strand of our strategy which is making good progress is the Tunnel Systems Sub Group. This group fills an important gap in tunnelling, literally. To date, most members of the ATS have been civil engineers who build the shell of the tunnel. But what goes into that shell includes many other disciplines including ventilation systems, lighting systems, control systems, rail systems, signalling systems and more. There are also the tunnel operators, who for years used to get handed a tunnel and subsequently say, "This tunnel has the same mistakes as the last one. Why don't they ever ask us what we need?" So, now we are asking and have a pretty vocal and vibrant Tunnel Systems Sub Group.

Those two are the initiatives we've made the most progress on, but another strand I'm keen to get some energy behind is the voice of industry. The ATS wants to establish ourselves as the voice

for tunnelling in Australia i.e., the experts called upon for comment for all things tunnelling related. I've had a couple of media interviews and I'm hoping that the media will turn to the ATS more often. I'm also talking to various client bodies, such as Transport for New South Wales who are delivering the most tunnels in Australia right now. We're meeting regularly to provide feedback on what our members are saying about how we can improve communication, improve outcomes and interact better.

Education and research is another strategic strand with a number of initiatives underway. We are also focused on improving our relationship with peer organisations. We've got a reasonably close relationship with the New Zealand Tunnelling Society but we're keen to connect more with tunnel societies in Singapore, the UK, the U.S. and Hong Kong etc. We envisage a situation where an ATS member can go to London, for example, and attend a BTS meeting as a reciprocal member.

Being the ATS President has been hard work in some ways, but it's made easier by the fact I'm surrounded by such an enthusiastic group of people. I see my role as helping and facilitating their ideas while keeping our activities strategically aligned and focused. It's a pleasure to work with such great people and I'm constantly amazed by what they are able to do and achieve. Particularly because they are all volunteers. To be part of that group, and to give guidance and suggest strategies that my colleagues will then go and execute to the best of their abilities, is something I'm very proud of."

A wise elder of the tunnelling game



As the immediate Past President of the ATS with over 60 years' experience as an engineer in Australia, and 40 of those in tunnelling, Ed Taylor is one of the Society's wise elders. He was an instrumental member of the organising committee for the 13th ATS conference in Melbourne 2008, chaired the 2011 ATS short course and won the Allen Neyland Tunnelling Achievement Award in 2017. Ed is not only

one of Australia's tunnelling greats, for his pivotal involvement in the delivery of the majority of major tunnel infrastructure projects to be delivered during his career, but his lasting legacy will be his dedication and encouragement to the people who work in the industry. He is currently a casual employee of John Holland working in the tunnelling design and engineering space.

"I commenced in the tunnelling game in the early 1970's working with the then Melbourne and Metropolitan Board of Works building trunk and main sewers using open faced hard rock TBMs (Robbins and Calweld). At that time there was also soft ground shield tunnelling under compressed air and ground freezing for shaft excavation, so generally very exciting times. Since the mid 1990's, I have worked on large road tunnel projects in Melbourne, Sydney and Brisbane. Recently I assisted the design and construction teams in the early phase of the Melbourne Metro rail project and, in particular, the two challenging mined cavern stations in the CBD.

I became aware of the ATS (or Australian Tunnelling Association as it was then known) shortly after it was

established in the mid-1970s when a few colleagues and my boss got involved. They encouraged me to join too but I didn't at that point because I ended up moving away from tunnelling into the water industry. When I returned to tunnelling approximately 15 years later, I joined the ATS straight away. That was nearly 30 years ago.

I was on the Victorian Committee first, then I became the Chair of the Victorian Chapter (and therefore joined the National Executive Committee as the State representative). After a number of years on the Executive I started to develop some strong ideas about the direction of the organisation. I felt that there were some issues that the Executive was not resolving in the best interest of the members and at one point I made my views quite clear. Maybe as a result of speaking up, I ended up with the top job. That was in 2014.

Prior to assuming the President's position, there were some tensions in the relationship between the ATS and the 'umbrella' organisation of Engineers Australia (EA). I felt the ATS had an important role to be the voice of what was going on out there in the broader tunnelling industry and, without dwelling too long on it, I didn't feel the ATS was given enough independence or trust,

"My involvement with the ATS has had its challenges at times, but it has always felt important and an organisation there for the greater good, which makes belonging and participating really rewarding."

even though we were a viable, well-run society.

A key differentiating factor about the ATS, as compared to other technical societies in EA, is that ours is an industry association. It is not purely for engineers in tunnelling, we also have non engineer members, something that was unusual in the EA world. We even considered becoming an incorporated body in our own right, but there are many downsides to that and, eventually, after the careful development of an improved mutual understanding, we now have a much better working relationship with EA.

I think the right approach is to try to grow together with EA, whilst retaining our independent voice in respect to tunnelling matters. For example, if anybody approaches EA wanting to know about tunnelling - any government

body or the media etc - they should automatically be referred directly to us as the 'centre of excellence' in that field.

In 2019, I stepped away from the President's role and Harry Asche took over, which was just brilliant. Harry and I hold similar views about many things and it has been great to see him take the new ATS Strategy forward and make progress in many new initiatives.

My involvement with the ATS has had its challenges at times, but it has always felt important, an organisation that exists for the greater good, which makes belonging and participating really rewarding. This is just a personal opinion, but I have always felt it's important to give back to the industry that has supported and helped you to grow so much."

The most enjoyable project of my career

The Eastlink project in Melbourne definitely fits into this category. These were twin, three lane road tunnels mined using road headers and lined using an innovative pre-cast invert and the arch being cast in-situ, all fully tanked. I started working on it in around 2002 having recently finished the Melbourne Citylink and a period on the Lane Cove project. The Citylink had a lot of problems and I was determined that Eastlink would be different. I was part of the tunnel team's executive and it ended up being a model project, the best I've ever worked on in the sense of great teamwork, great physical outcomes and being enjoyable. The safety and quality culture were positively driven right from the outset. We had a fantastic superintendent, Harry Lyle, who scrutinised everybody we employed. The technical problems were investigated and solved appropriately, assisted by an excellent working relationship between the design and construction teams. We had a black-tie ball in the tunnel for the opening ceremony. Great lighting, delicious food, a stage, clients and dignitaries, as well as workers. We ate and danced on the future roadway which was a fitting way to complete an enjoyable project.



East link project

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Melbourne Underground Rail Loop, 1978

Melbourne Metro Tunnel, 2021



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Building the society, building friendships

Now enjoying his retirement in New Zealand, Simon Knight's long and successful career led him to become an executive leader, directing teams of professional engineers in the mining and chemical industries in several different countries. Simon was Chair of the ATS for nine years between 2006 and 2014, and looks back on this time fondly.

I really enjoyed working as part of the ATS National Executive Committee. The desire to do the best for the ATS membership guided all our efforts, even when it meant questioning the status quo and our being part of the bigger Engineers Australia, or conforming to the edicts of the International Tunnelling Association (ITA)..

Other than some hiccups at the start of my Chairmanship all was unity within the committee. We got together and enjoyed our regular meetings around Australia and New Zealand. I really looked forward to these meetings and value the friendships that were built up within our ATS committee and indeed

with members of the ITA committee who were rather more eccentric than our home-grown members. All the national caricatures were amply reinforced by their respective representatives. (I guess we were the same!)

Committee members singly and jointly contributed to some solid work in codes of practice and such like. Being practicing members of the industry allowed us to be most pragmatic and avoid being overly bureaucratic.

The Australasian tunnelling industry is quite small in world terms, however we always performed above our weight when it came to safety and innovation.



When convenient we would combine our committee meetings with a site visit so, over the years, I was able to see some fascinating bores (in the engineering sense) around Australasia. One that springs to mind was the Waterview tunnel in Auckland. At 2.4 kms long and six lanes wide it was most impressive going through on foot, one feels very small in such a space.

I treasure the memories of my time on the ATS Committee and offer my appreciation to the current and future volunteers in the Society.

A tunneller from the get-go

Peter Kessler is CEO Director - Construction Operations of Taylor Rail. He has worked for a total of 20 years in the tunnelling space with extensive global experience across Australia, New Zealand, Philippines, China, Hong Kong, Singapore, Malaysia and Europe. He was Chair of the ATS between 2002 and 2005.

I was born during the Snowy Mountains project. My father was one of the prominent superintendents on several of the hydroelectric tunnels and shafts of the time and was underground when my mother went into labour with me. He had to take a loco out and drive through the snow for two or three hours to get to Cooma for my delivery. Bottom line: tunnelling was in my blood from the get-go.

I started in mine development in 1985 and then progressed to NATM (New Austrian Tunnelling Method) drill and blast, pipejacking, hard rock and mixed ground TBMs, ground freeze, large shafts and large roadheader road tunnels.

I joined the Australian Underground Construction and Tunnelling Association (AUCTA – the forerunner of the ATS) sometime in 1999 when I was Executive General Manager of Transfield, an



international tunnelling business and then, market leader (developer, builder and operator of tunnelling infrastructure) in South East Asia and Oceania. In 2003,

John Holland bought all of the national specialist businesses of Transfield and so Transfield Tunnelling became John Holland Tunnelling and Mining.

From late 2002 to early 2005, I was the ATS National Chair and, for the subsequent two years (as was the custom), immediate Past Chair. I resigned from the ATS after approximately eight years in 2007 for a couple of reasons. One, I felt that rejuvenation of the National Executive Committee was important and two, I'd accepted a role running the regional (southern) business of John Holland. My decision on that day seemed to spark the (healthy) retirement of several other long serving members which made way for some new representatives.

I'm really proud of my contribution to the Society and the achievements of the National Executive while I was a member. These included commencing the process to change our name from AUCTA to ATS; boosting ATS membership in all chapters by around 100%; adding New Zealand as a chapter to the Society, and encouraging cross-Tasman collaboration; and commencing the cutting edge activity (at

Peter Kessler and the Eastlink Tunnel team 2006 (L-R, Matt Phelan, Peter Kessler, Martin Harvey, Tony Avard, Craig Farr, Harry Lytle) – Thiess John Holland Joint Venture.



the time!) of creating a website - which I helped design and manage.

We also commenced the Young Engineers "David Sugden" Award, and I had the honour of presenting the first of those awards to Anmol Bedi in Hobart, Tasmania in 2004. Also, during my involvement, the ATS funded and co-authored (with NSW Workcover) the new National Code of Safety for Tunnels under Construction. I believe this Code was later adopted by most other states.

On behalf of the ATS, I joined the Australian Civil College Board to give the tunnelling sector a bigger voice and, in other outreach activities, I helped the ATS form a special tie with the Norwegian Tunnelling Society with whom we ended up collaborating on several technical fronts after they hosted a delegation to Australia in 2005. We also sent a delegation to Hong Kong to promote the Alliance Contracting models that had been trialled in Australia in the tunnelling sector and presented at the Hong Kong Polytechnic Institute.

Another memorable event was helping the ATS publish its first book: A History of the Development of Performance Predictions for Hard Rock Tunnel Boring Machines, a compilation of technical papers by world-class Australian tunneller David Sugden.

My lasting impression of my involvement with the ATS was that we had a lot of fun and I look back very fondly on those years. It's very gratifying to see this level of energy and commitment has continued to the present day and all the hard work currently being done.

The Sydney Harbour Catchment Project

In 1998, Sydney Water took the bold step to award the largest public sector Alliance contract globally to Transfield, MWH and Connell Wagner that aimed to dramatically improve the quality of the Sydney Harbour catchment. This was to be achieved by providing storage capacity for 500 million litres of storm water and wastewater that historically ran straight into the harbour without treatment.

The new relief system collected water at four major north Sydney overflow sites and then transported that water to the North Head Wastewater Treatment Plant. This mammoth project required a series of large diameter bored tunnels by hard rock TBMs and large storage caverns excavated by roadheaders. Several shafts were also sunk (and raise bored) to and from tunnel level.

In total, 22km of tunnel was driven with four TBMs of 3.8m to 6.6m diameter. While the host rock, Hawkesbury sandstone generally behaved itself, the tunnelling was not without challenges. The

existence of valley bulging proved problematic on the Scotts Creek drive for the double shield Robbins with the interception of very blocky ground and significant harbour connected inflows below Middle Harbour required a major retrofit of the open beam TBM driving west from North Head to permit full radial forward grouting. This grouting campaign was cutting-edge and ultimately reduced inflows by some 95% which allowed the project to be successfully completed.

Under serious time pressure, the project beat its target of being operational prior to the commencement of the Sydney Olympics where Sydney Harbour was then able to deliver on the world stage.

The ultimate reward for the effort of so many people was to see the return of whales into the harbour several months after the project completed. This delightful observation of two whales under Sydney Harbour Bridge was the first for Sydneysiders for decades.

Inviting the world to Sydney

Having started his career in civil engineering in Victoria and being involved in several underground projects, Garry Ash decided to join the Australian Underground Construction and Tunnelling Association (AUCTA) in the 1980's so he could further build his interest and knowledge. At the end of 1999 his colleagues on the National Executive asked him to Chair both AUCTA and lead the organising committee for the General Assembly and World Tunnel Congress, due to be held in Sydney in 2002.

"I started working in the construction industry in 1964 as a cadet engineer for the then small company Leighton Contractors on the (now demolished) BP Refinery at Crib Point in Victoria. I was transferred in 1966 to work as a site engineer on the St Kilda Junction underpass and road reconstruction project, where the Melbourne and Metropolitan Board of Works were the construction authority for the Victorian Government. These projects provided me with an excellent grounding in the civil engineering industry as well as an introduction to shaft sinking and small tunnel drives.

My first major underground project was the North Road Pumping Station in Victoria which commenced in 1968. It was interesting because it was one of the first projects where authorities across the country were starting the process of moving from authority-led to



President of the ITA, Professor André Assis, congratulates Garry Ash at the end of AITES-ITA Downunder 2002, the 28th World Tunnel Congress held in Sydney.

contractor-led construction.

I started as Project Engineer and completed the job as Project Manager and benefited enormously from the wonderful blend of expertise and learnings from the Snowy Mountains

Authority workforce allied with the expertise of hard rock miners from Kalgoorlie in Western Australia. All these skills were put to use in almost all elements of underground construction including caisson sinking through soft ground, rock shaft sinking, hard rock tunnelling at depth and heavily reinforced concrete works.

As a member of AUCTA, I was involved in various local congresses, technical sessions and events as were most other members, but my involvement really ramped up towards the end of 1999 when Australia was awarded the hosting rights for the 28th World Tunnel Congress (WTC) by the International Tunnelling Association (ITA), which was to be held in Sydney in 2002.

Looking back, I don't think anyone on the organising committee (which consisted of delegates from each of the state chapters) fully appreciated the load on all our shoulders that organising such an event would entail, particularly as most of us simultaneously continued to work in our full-time operational roles. This burden was tragically exacerbated by the terrible events of 9/11 just six months before the congress, but we decided to press on, albeit with not as many visitors and presenters as previously thought.

Despite the challenges, we supported

Reflections on an iconic project – the Sydney Harbour Tunnel

"One of my most memorable projects (others included Brisbane Rail Tunnel duplication and Elgas Gas Caverns under Port Botany) was working on the Sydney Harbour Tunnel. I was the Project Director for the Concrete Kumagai Joint Venture (JV) which was contracted to execute the south shore works. This encompassed driven tunnels through hard rock (and successfully using roadheaders for the first time in Australia); soft ground tunnelling under the forecourt of the Opera House; the staged underpinning of the Opera House seawall; the construction of a large cofferdam; and linking to the Immersed Tube Units installed by Transfield as a

separate contract to the main JV. Not only was the project iconic in terms of its vicinity to the Opera House, the Sydney Harbour, the Tarpeian Way cliff face and several old (by Australian standards) state government buildings, it was on the cutting-edge of what was possible at the time. The project had a requirement that there be no ground settlement anywhere and this was achieved.

Other notable components of the Sydney Harbour Tunnel project was that the concept was initially developed by the Transfield Kumagal JV and then developed as a BOOT project (Build, Own, Operate, Transfer), which was an Australian

first. Part of the agreement with the NSW State Government was that some of the physical works would be carried out by the proponents of the project and other elements (such as the south shore works), would be tendered to the local industry. The project also required, to a very high degree, total integration with all the different elements of the approval, design and construction process; more so than usual due to the unique nature of the works in and around the Opera House and forecourt.

The project has been an outstanding success since its spectacular opening in 1992, and continues to be an exemplar project for the Australian tunnelling industry."

each other well. It was a great team effort and the Congress was deemed to be a success. I remember writing in my Chairman's Foreword to the proceedings for the WTC "... in Australia we are about to embark on a series of major underground engineering projects..." but I don't think anyone at that time could have predicted the amazing amount of underground work that has been completed across the country since then.

The Australian tunnelling industry has much to be proud of, and AUCTA (now the ATS of course), and all its loyal members, has contributed to that significantly. Reaching the age of 50 in such good shape is a singular achievement and I'm certainly proud to have played my own small part. I would encourage all those in this wonderful and vibrant organisation to continue this high level of engagement. Building on these foundations will lead to an even stronger and more effective voice for the underground industry in the future."



The start of the approach to the main tunnel of the North Road Pumping Station.



The sinking of the caisson onto a sloping rock face for the North Road Pumping Station.

A job well done

Tony Peach – ATS Chair 2005 – offers his congratulations to members past and present.

"As the former AUCTA, and today the ATS, it is quite remarkable to witness the 50th anniversary of the Society. Even more remarkable is that I commenced in the industry during the mid-1960s while working for the Tasmanian Hydro Electricity Commission on the "Poatina" Mole, then the Wilmot TBM, then moving to the Robbins company engaged on the Thompson Yarra project TBM, then the MURLA TBM modifications, all before our auspicious organisation commenced.

Notwithstanding this reminiscence, I offer my congratulations to the multiple office holders over the decades that have transpired since the founding of today's Society. To those that have tirelessly volunteered their time, helped the organisation grow to what it is today, thank you for a job very well done."



ATS on the world stage

As one of the 19 founder nations of the International Tunnelling Association (ITA), the ATS (and its forerunners) has always been influential on the world stage, not just in organising, but also in creating innovative technologies that move the industry forward. In the early days this included the world-famous TBM Melbourne-head and the Mobile Miner at Mt Isa in Queensland, but as we'll soon see in Dr Anmol Bedi's story, the innovative talent of Australians is still alive and kicking, even if they now live on the other side of the world.

From the early days right through to today, ATS members have travelled overseas to represent Australia at international events such as the World Tunnel Congress (WTC), or to pitch to host international events in Australia, as remembered by ATS founding Chair, Dr Bill Bamford:

"I was a member of the organising committee for the WTC which was held in Melbourne in 1987, and participated as co-Chairman of the ITA 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 ITA and WTC. At the Oslo meeting in 1999, I presented Australia's winning bid to host the WTC in Sydney in 2002, which only just defeated Singapore's rival bid, which was vigorously presented by Jian

Closing Ceremony
 Andre Assis, ITA President expressed gratitude to AUCTA for organising the congress. He especially noted that the ITA Open Session, organised in coordination between ITA and AUCTA, was a strong response of our community toward understanding and solving problems that could jeopardize the use of underground solutions."

He then presented two ITA medals: one to AUCTA, and the other to Garry Ash, the congress chair and AUCTA President.

He urged congress participants to disseminate the reports of ITA and to use the ITA web site. "The success of international organisations such as the ITA," he said, "relies on how member nations and participants work to disseminate the information gathered here."

Garry Ash said that the tunnel sessions had provided new information and generated vigorous debate. After showing a review of photos from the conference, he turned the podium over to Henk Oud, chair of the world tunnel congress and 29th General Assembly of the ITA, to be held in Amsterdam in 2003.

Oud noted that in the 10 years that have passed since the ITA World Tunnel Congress in Amsterdam in 1993, Green Heart Tunnel, part of the Amsterdam-Paris rail link, for example, exemplifies the demand for environmentally friendly transport links.

He showed a short video previewing the Amsterdam conference and highlighting Dutch tunnelling experience. The Dutch government has subsidized development of the underground solution and established the Centre for Underground Construction (COB) to further research on tunnelling in The Netherlands. In 2003, many tunnels will have been completed or still under construction, providing numerous opportunities for congress participants to view the tunnel works.

Garry Ash then introduced a didgeridoo player, who performed a closing musical piece, providing a splendid ending to a splendid conference.



Article from the AUCTA Journal, October 2002



At the Gala Dinner of the World Tunnel Congress 1987. Photo includes Claude Berenguer, the Secretary-General of the ITA (second from the left); Bill Bamford, ATS founding Chair (seated at the extreme right of the table); Sir David Smith, the Official Secretary to the Governor-General of Australia (third from the right); Frank Watson, the General Manager of the Melbourne Underground Rail Loop Authority (standing behind Sir David Smith).

Zhao, now Professor of Resources Engineering at Melbourne's Monash University."

Bill's 1999 efforts were not in vain. As described by immediate past Chair Garry Ash, in the AUCTA Journal of October 2022, "The Congress, was, in my view, a great success with total delegates of around 650, with a further 80 accompanying delegates. Feedback from all areas has been very positive and the ITA Executive was, in particular, very pleased with the quality and smooth running of the Congress. This has certainly helped in taking our relations with the ITA to a new level."

The ATS continued to play an active role in the ITA, as illustrated in Simon Knight's Chairman's Foreword to the AUCTA Journal in May 2015:

"We have been instrumental in changing the voting process for the WTC to make it more equitable and provide a higher quality outcome. We have sat on the good governance sub-committee and happily been able to validate the ITA claim to good governance. We have tried to make the mechanics of the General Assembly a bit more democratic and more like the United Nations model we base it on. There are Australian representatives in most

of the working groups and two ATS members are amateurs of their respective groups. I think we have punched well above our weight in this international forum."

Today, Australia's influence on the global stage continues to go from strength to strength with ATS delegates contributing to several international technical guidelines and sitting on ITA working groups that currently include: WG02 – Research, WG12 - Sprayed Concrete Use, WG19 - Conventional Tunnelling; WG21 - Life Cycle Asset Management; and ATS member, Dr Jurij Karlovšek, is the Animateur of WG22 - Information Modelling in Tunnelling.

Jurij is actually one of today's best examples of an ATS member going over and above in his efforts for the international tunnelling community. As we will soon see in his story, after initiating the now flourishing ATS Young Members group in Australia in 2013, he initiated and subsequently chaired the ITA Young Members (ITAYm) group in 2014. The ITAYm is now a thriving umbrella organisation which works with the 74 ITA member nations to further the development and engagement of the next generation of tunnellers. According to Jurij, it wasn't the simplest process, but he got there in the end:

"To create the ITAYm, I first worked to amend the bylaws of the organisation to properly position the young members group. We didn't want ITAYm to be a working group, or part of the committees, we wanted it to be a separate platform for individuals to be able to view the organisation as a whole first, before they decided where they were best suited."

ITAYm is now well established with more than 30 member nations having started their own young members groups. In large part for his work setting up ITAYm, Jurij won the ITA Young Tunneller of the Year Award in 2015. He continued as ITAYm Chair until 2018 when he passed the mantle on to his fellow ATS member Keith Bannerman (also profiled in this journal) who lent his tremendous energy to the position until 2021.

In 2022, this celebratory 50th anniversary year, it is gratifying to report that longstanding ATS member, Professor Arnold Dix, was elected as President of the ITA. He was voted in on a progressive agenda with a focus on helping the tunnelling industry face up to, and help solve some of the biggest challenges we face in the 21st Century. We will hear his story soon.

AUCTA gives rousing Bicentennial Lecture to the BTS

In 1988, the British Tunnelling Society (BTS) invited AUCTA to talk to them about developments in tunnelling as part of Australia's bicentennial celebrations. Chris Windsor's lecture on Australian tunnelling and construction convinces the Brits that Australia has lost "none of its zest for breaking new ground."

In the extract from the AUCTA Journal in July 1988, Chair of the day, Allen Neyland, introduces how it went:

BICENTENNIAL LECTURE TO BRITISH TUNNELLING SOCIETY

The British Tunnelling Society invited the Association to talk to them on Australian tunnelling and we were fortunate that Chris Windsor was able to take up the challenge on our behalf. Chris, whose own knowledge of the Australian underground is extensive through his geotechnical work with CSIRO (and also as editor of this publication), was able to gather additional information and slides from other committee members for his presentation early in May. His talk was well received. The Bicentennial imprimatur is a bit of a mystery, but we assure our readers that it was quite an honorary appellation.

We reproduce here the summary of the proceedings for a well known international journal. Our readers may find some of the adjectives a little on the florid side, but perhaps it is better to be noticed in this way than ignored.

"A COMMEMORATIVE BICENTENNIAL LECTURE — "A REVIEW OF AUSTRALIAN TUNNELLING AND UNDERGROUND CONSTRUCTION" given by C.R. Windsor to the Institution of Civil Engineers, British Tunnelling Society, London, 5 May 1988.

In a review of Australian Tunnelling and Underground Construction emphasis was placed on the more interesting and novel approaches that have been developed and practiced by the Australians over the years. Particular attention was given to projects of the late fifties and early sixties such as The Snowy Mountains Scheme and the Poatina Power Project where ongoing site investigation, stress analysis and response monitoring were first integrated into the design and construction process. In the discussion that followed, Sir Alan Muir Wood suggested that this methodology could be called the New Australian Tunnelling Method. In reply, Chris proposed that to avoid the possibility of a spelling mistake confusing those already confused by another term [NATM], a better and probably more accurate name would be the Old Australian Tunnelling Method.

A chronological history of the TBMs in Australia was also presented starting with the Robbins 161-108 that broke all the existing world drivage records at Poatina in the early sixties. This first machine was followed by the award winning and the world famous Australian modifications to imported machines in the sixties and seventies, and the fully designed and manufactured machines through the seventies. Examples were given from the construction of the Deep Main Sewer Network and the Underground Rail Loop in Melbourne. This history wound up with a brief review of the research and development work that is continuing into the eighties on the Robbins Mt Isa Mines "Mobile Miner" in Queensland and in Victoria on the MMBW Robbins machine with its fully automated, on-board data acquisition system.

Chris also gave a brief review of some of the more recent projects; The Ski Tube, The Western Trunk Sewer, The Ocean Outfalls Project, The Sydney Harbour Tunnel which clearly indicate that the Australians have lost none of their zest for breaking new ground'.

From the tunnels of the Snowy to ITA President

Arnold Dix's fascinating range of interest areas and enduring quest for justice has seen him develop quite the eclectic CV. He is an accomplished lawyer, environmental scientist and engineer with significant expertise in tunnels, risk and transport. He was officially recognised by the ATS in 2011 when he was awarded the Allen Neyland Tunnelling Achievement Award with the judges noting:

"The Australasian Tunnelling Industry is indebted to Arnold, not just for the substantial contribution that he has made to our domestic tunnelling practice, particularly in the fields of fire and life safety engineering, but also for the promotion of our local practice to the world at large."

With a disarming mix of humility, charisma and great pragmatism, Arnold has just stepped into the world-changing role of President of the ITA, bringing with him a unique vision for the future of the underground.

In this, the 50th year of the ATS, I've just become President of the International Tunnelling Association (ITA) which, from an Australian point of view, is quite a big deal. So how on earth did that happen?

As a small kid I lived for a spell in the Snowy Mountains and visited the tunnels of the Hydroelectric Scheme and they were just awesome, they really captured my imagination. I'm not from an intellectual family. My parents are hotel keepers and I grew up in a pub, cleaning tables and washing dishes, so it was to the great disappointment of the family that I went off to university.

I studied geology and science and, because I'm passionate about the environment, ended up doing a piece of post graduate research at the Ranger Uranium Mine in the

Northern Territory. This got me in trouble with the Australian Government because I became too vocal about my environmental concerns and the fact that Australia was selling uranium to France for their nuclear weapons program. I was told, pretty bluntly, that if I continued to speak publicly, my career as a scientist would be over.

Well, that got me riled so, in 1985, I decided to study law and before I knew it, I was a lawyer in a top tier law firm with a growing reputation for my ability to hold governments to account (from an environmental perspective) on their big infrastructure and mining projects. This reputation led, in 1998, to the government in Victoria bringing me in on the City Link Tunnel Project in Melbourne, not necessarily because

they wanted my involvement, rather they didn't want me to be against it.

This case went well and my reputation and passion for the underground grew so much that the NSW government sent me to Europe in 2000 on an information gathering mission for a case. I'm guessing the Europeans must have thought, "Look at this cool little Australian fella who's a geologist, a lawyer and a scientist and who loves tunnels," because they asked the Australian Government to appoint me to PIARC (the peak world road authority). I was then appointed to PIARC for road tunnels and have maintained my roles there for more than 20 years.

Then, in 2001, the Twin Towers disaster happened and changed everything for me. An Australian Government agency appointed me to investigate and so I went, as a matter of urgency, to New York. Because of some work I'd already done in the U.S., many people from the New York Port Authority were my friends and colleagues so I could access Ground Zero fairly easily, but doing that work was one of the most challenging experiences of my life.

By that point in my career, I was a successful barrister with a highly technical, engineering, scientific and environmental focus. At just 34 years old, I'd been made partner by a major law firm and was being paid a phenomenal amount of money. But returning to Australia after 9/11, I found that nothing made sense. The only thing I can liken the feeling to is perhaps a soldier coming home from war so, at the end of 2002, I quit my legal partnership (which is completely unheard of) and set up my individual practice as a barrister again, specialising in the underground.

I continued to love international work and in 2004 I was appointed to NFPA 130 the international standards body for underground rail, and a year later I was appointed to NFPA 502 – the road tunnels standards committee too. I had an absolute ball doing that, working on underground metros as well as road tunnels in the U.S., in my capacity as a lawyer, while also still working as a scientist on various other standards bodies doing investigations. This year (2022) NFPA awarded me their prestigious Committee Service Award for distinguished service to the development of Codes and Standards.

My international work has also taken me to Albania, building tunnels into Kosovo so the military could do intervention in the war with Serbia, and I've worked in Africa, South America and the Middle East in all sorts of



Dix (centre) 1983 Monash University Geology class

Arnold Dix is brought in to work on the City Link Tunnel Project in Melbourne in 1998, a project which ignites his passion for the underground.



On site at Melbourne's Metro Rail



interesting and ethically-challenging environments. I've also worked closely with the world's re-insurers because when the Twin Towers collapsed so did the insurance industry for tunnels. That's how I got involved with the International Tunnelling Insurance Group (ITIG) and that's what ended up propelling me into the ITA in 2003, where I was the Animateur of the Contractual Practices Group for over a decade and, in 2017, appointed to the Executive Council.

Because I was a hybrid lawyer/technical person, I think I was found to be useful because I could transition seamlessly between my brown-cardiganed self and my lawyerly wiggled official self to navigate through extremely complex commercial and legal matters. For ITA, it meant I became instrumental in big initiatives to change how the world thinks about how we contract underground. The ITIG set up a code of practice for risk management, and I helped make that international, even bringing the recalcitrant Brits on side. I also initiated a specialist underground contracts project with International Federation of Consulting Engineers (FIDIC) and am now looking to New Engineering Contract (NEC) for a new underground contract for the world.

All those experiences have set the scene for where I am now: a completely independent person who is fiercely in search of the truth of things. This quest has taken me all over the world as the investigator of choice for terrible disasters because my clients know I give direct, transparent and honest advice about how and why accidents have happened and people have been killed. I've developed a reputation for not

“All those experiences set the scene for where I am now: a completely independent person who is fiercely in search of the truth of things.”

being partisan. I tell people the truth and I don't gild the lily. If I do take something on, it's never for the money. I'm doing it because it's the correct position to take from an ethical point of view. I've also never been bashful in clashing with powerful decision makers.

So now I'm in a powerful position of my own right - the President of ITA - and I have some big plans. For the last year, as President-Elect, I did a considerable amount of work behind the scenes to make sure I started my term heading up a united organisation. My mission is to make the ITA relevant, which means we must engage meaningfully with the narratives of the 21st century i.e., engaging on the global issues of sustainability, equality and the dignity of human beings.

The fact is, we live on a planet where most people still don't have access to clean water and a toilet and we, the ITA and all our affiliates, have the knowledge and expertise to solve this.

We know how good the underground is for things like water and sewerage and transport and energy. But we also know how expensive going underground is, so our job is never to go into a room with a decision maker in a country which is poor, where they haven't got education, where their roads are potholed, where their people are dying of dysentery, and recommend that they divert GDP impacting resources into building a lovely tunnel unless we've got a very compelling case.

This is the mission I took to the ITA when I was petitioning to lead, and that message seems to resonate well now, (although even in quite recent times, to talk like that I think I would have been seen as unhinged). But the world is different now and changing fast. I'm completely refocusing ITA's strategic plan and I'm urging my colleagues to pay attention to the declared UN climate emergency and that we need urgent policy changes to suit. My message to my colleagues is: Let's not be shy. Let's put on our brown cardigans, do our buttons up and get serious. Now is our time to shine.

The ATS has a role to play in all this of course, and my vision for the Society as it travels into its next 50 years is that it becomes the informed advocate for the combined professions of the underground in Australia. In a world of climate change and where intergenerational equity is increasingly important, I hope my ATS colleagues continue to get better at explaining to decision makers and the public why Australia needs the underground for many vital things including power, transportation, sewerage, water and perhaps even agriculture.



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Q&A with Dr Anmol Bedi

Dr Anmol Bedi was the inaugural recipient of the David Sugden Young Engineers Writing Award in 2004 and, as a result, was elected to the National Executive Committee as the first Young Tunnelling Representative. According to the journal of the day his role was to, "add a young perspective to our activities going forward." He remained on the ATS Executive (or AUCTA as it was then known) until 2007 when he moved permanently to the UK. Here he set up his own firm, Bedi Consulting, a specialist tunnel and geotechnical engineering firm whose services and innovations have achieved international acclaim.

Why did you first get involved in the ATS?

Given the growth in tunnelling and future potential at that time, I thought it was vital the ATS invest in attracting and developing young engineers. I was fortunate to meet some great individuals on the National Executive Committee who were not just knowledgeable but great fun. I'm still in contact with them, both socially and professionally.

What got you into tunnelling in the first place?

I was attracted to tunnelling during my undergrad degree in civil engineering. After doing all the modules, I realised no one teaches tunnelling, but rather geotechnics and structures, which form its basis. The practical side of things seemed to be learned on the job and this sparked my curiosity.

How did it feel to win the first David Sugden Young Engineers Writing Award?

It was a nice surprise! I never considered myself good at writing, but really enjoyed the technical aspect of things. Winning the award was a bit of a confidence booster!

This led to you becoming the first Young Tunnelling Professional to be elected to the ATS Executive in 2004. What was your mission in this role?

My main goal was to promote the ATS to students and early career engineers in order to gain interest in, and hopefully enter, the tunnelling fraternity. At the time, there were no members below about 40 years old in the ATS and we all saw the need to invest in the future of the industry. As a gap that needed to be filled outside academia, the ATS was a prime vehicle to attract new talent. I wrote to the National Executive Committee offering to start up a young members division, and they said OK!



How did you make your views heard as a younger member among all the older professionals?

The Committee members, at the time, were all legends, real pioneers of tunnelling in Australia, but they were also an ageing lot (I say that slightly tongue-in-cheek!). There was recognition among them that it was important to have a young person on the committee that new members could relate to. I had an item on the agenda at each meeting to say my piece and they also set up schemes like the David Sugden Award and invited new young members to give talks and get actively involved. Very soon I felt comfortable and important to be on the committee – which being young and nervous, was intimidating at first – and this allowed me to do the job they intended.

Do you do anything now to nurture up and coming professionals?

I now employ graduates in my consulting

firm, and try to pass on the same lessons taught to me by the senior members of the ATS and other organisations I've been part of. Our firm also works with universities to support PhD and MSc students that want to advance their knowledge and career in tunnelling.

How did it feel when your company won the NCE Technical Innovation of the Year Award, and was runner up in the ITA Technical Innovation of the Year, in 2020?

It was a pleasant surprise on both counts, particularly because we are such a small consultancy (less than 10 people) competing against large multi-national organisations on the world stage! Again, a real confidence booster.

What was the technical innovation?

We developed a novel system of using 3D laser-scanning and point cloud survey to assess the condition of existing tunnels. We worked with Network rail, who own over 700 tunnels across the UK, with an average age of over 100 years old, although some are over 150 years old.

These tunnels are typically masonry construction, built in the Victoria era by Brunel, and Network Rail have the tortuous task of inspecting and maintaining them. This is currently done manually with experienced inspectors walking the tunnels at night with flashlights and drummy hammers, taking notes on paper. This process is time consuming and has repeatability issues.

Our method allows a whole tunnel to be captured in a single night, after which we build a digital twin with millimetre accuracy. Our algorithms then rapidly processed the data offline, and identify and position defects. This can then be reviewed by Network Rail inspectors and asset engineers who decide what needs to be fixed.

What is the most interesting project of your career and why?

Victoria Station Upgrade (VSU) in London was by far the most challenging and rewarding project of my career. It was a complex project at the centre of a major transport interchange that weaved around a dense population of residents and stakeholders, including two longstanding Grade II listed theatres. Existing infrastructure including major sewers, water mains and existing London Underground tunnels.

My role started in 2007 on the early scheme design as a graduate engineer, then I moved on site between 2013 to 2016 as the Senior Sprayed Concrete Lining Engineer, right up until the last advance was sprayed. It was a fantastic

project, with a great team, dealing with many hairy moments, which we all worked through safely together. During the works, the station remained open at full capacity and all ground movements were managed within design limits. All in all, nine years of my life, and now I get to walk through it as a paying customer using the London Underground!

Do you have a message you'd like to relay to current ATS members on this monumental occasion?

Congratulations to the ATS on reaching the 50-year mark! From the Snowy Scheme to now the committee and members over the years are to be congratulated for making Australia an eminent tunnelling nation. Well done and keep going ATS!



Anmol's team developed a novel system of using 3D laser-scanning and point cloud survey to assess the condition of 100-year-old tunnels in a single night

On becoming the Australasian Tunnelling Society

In early 2005, Auckland-based tunneller Evan Giles (Project Director, WSP New Zealand) was invited to attend AUCTA's National Executive Committee Meeting in Brisbane, just prior to the 12th Australian Tunnelling Conference. During the meeting, the Committee asked whether he would be interested in establishing a New Zealand Chapter of the organisation, to augment the chapters already thriving in NSW, Victoria, Queensland and the chapter recently established in Western Australia (in 2004). Evan was immediately keen.

The Australian tunnelling fraternity has a long history of being inclusive and outward looking, always focussed on the development of the underground. In 2005, this desire led to some very warm discussions between myself and the ATS National Executive in Brisbane. The meeting concluded with the agreement that I would champion the establishment of an NZ Chapter with seed funding provided by the ATS. Shortly after, it was also agreed that the organisation's name, which had recently changed from the Australian Underground Construction and Tunnelling Association (AUCTA) to the Australian Tunnelling Society, would change once again to the Australasian Tunnelling Society to accommodate our new chapter.

I returned to Auckland inspired to make a start and arranged to meet with Andrew Cleland, then Chief Executive of IPENZ (now Engineering New Zealand). He affirmed support for a new technical society under the IPENZ Technical

Groups umbrella and successfully negotiated a formal understanding with Engineers Australia for the joint arrangement, with administrative functions vested in Engineers Australia. It was then time to canvas support from both individuals active in tunnelling and industry stakeholders in New Zealand.

Our first technical evening was held jointly with the New Zealand Geotechnical Society later in 2005, but from those humble beginnings of less than six tunnellers, our audience grew to over 50 people attending each of the six technical and networking evenings held each year.

By 2009, we felt we had sufficient strength in the Chapter to volunteer to hold the ATS's 14th triannual tunnelling conference in New Zealand. This was also to receive a name change from the Australian to Australasian Tunnelling Conference, a name that has remained ever since.

The result? In 2011, we held a most successful three-day conference



in Auckland. It drew around 400 delegates, including about 30 from outside Australasia. It was a technical and financial success which boosted the society's reserves and enabled us to invest in the development of emerging professionals.

In 2018, as we approached the third decade of the new millennium, it seemed appropriate for New Zealand to consider retaking a chair at the ITA as a country member. As such, New Zealand withdrew from the ATS, which reverted to the Australian Tunnelling Society, and the New Zealand Tunnelling Society was born. Since then, we've strived to keep in close contact with the ATS for whom we have the warmest respect. We are grateful the ATS helped engender the growth in technical and general interest in tunnelling across New Zealand, and provided the support and groundwork for our future success.

ATS today

Governance

From the start, the Australian Tunnelling Association (or ATA as the ATS was first known) was jointly sponsored financially by the AusIMM and IEAust (Australasian Institute of Mining and Metallurgy and Institution of Engineers Australia, respectively), who took it in turns to organise the periodic conferences, including the 1987 World Tunnelling Conference in Melbourne.

Inaugural Chair of the ATS, Dr Bill Bamford has commented, however, that AusIMM were more active, particularly because they retained an active involvement with an official representative on the AUCTA National Executive Committee (ATA had now been renamed the Australian Underground Construction and Tunnelling Association – or AUCTA). Says Bill:

“The leadership of AusIMM, under Beryl Jacka and later Bill Vance, were far more friendly and well-disposed to AUCTA than was the IEAust, who retained responsibility for the secretarial functions. After the move of the national headquarters to Canberra in 1978, two dedicated staff members looked after the interests of ATA and AGS [Australian Geomechanics Society] at ‘no cost.’ Later, in 1982, the staffing was reduced to one and, subsequently, in 1986, [after ATA had changed to AUCTA] the

support ceased to be provided gratis. As part of the IEAust’s ‘learned society’ responsibilities, AUCTA was, from that moment on, mainly supported in its activities by membership fees.”

This remains the case today, with the welcome addition of support from industry sponsorship through the Platinum Sponsors and the Gold and Silver Corporate membership; the financial boost provided at each triannual tunnelling conference; but most of all the commitment of the volunteers that come from the industry to support the organisation. Without them, none of what we do would be possible.

Structure

The structure of the ATS both has and hasn’t changed in the last 50 years, compared to the original proposal for the society. Unlike the British Tunnelling Society, which is London-centric, the ATS is state-centric with organising committees – known as chapters – established in Victoria, NSW and Queensland initially. These were joined by the Western Australia Chapter in 2004 and the New Zealand Chapter in 2005. New Zealand remained until 2018 when they left to form the New Zealand Tunnelling Society (an event which is covered in more detail by Evan Giles in this journal).

These chapters sit underneath an overarching National Executive Committee of 10 people, the composition of which must include members from all state chapters, at least one female tunnelling professional and one young member.

What has changed since the establishment of the organisation in 1972, is that the internet and improved communications has enabled the introduction of new special interest groups such as the Young Members group, Diversity in Tunnelling Sub Group and the Tunnel Systems Sub Group. This means the ATS now has a matrix structure, where members can be part of and contribute to multiple groups no matter where they are located (a young female, tunnel systems engineer under 30 who lives in Sydney may wish to join all of the above, as well as the NSW Chapter, for example). Since 1999, the ATS has also been home to the Shotcrete Society.

Aims and objectives

The overarching aim of the organisation is to help our members (which include contractors, designers, client representatives, asset operators, academics, suppliers and manufacturers) to achieve success in all aspects of their professional life through:

- Stimulating a better understanding of the underground domain by governments, planners and the community by being the voice of the tunnelling industry;
- Promoting and reviewing research and development of subsurface projects;
- Maintaining affiliation with the International Tunnelling Association (ITA) through active membership, including participating in ITA Working Groups;
- Communicating and linking with other local and international likeminded associations concerned with the application, planning and practice of subsurface development and utilisation, and;
- Reviewing the adequacy of education and training of technologists associated with the science, engineering and practice of subsurface development.

Into the future

As the ATS celebrates its 50th year and looks to the future, the current structure – which is explored in more detail over the next few pages – will enable it to be the voice of an ever-growing professional industry that has to adapt to the modern world.



ATS National Executive Committee, pictured at the Australasian Tunnelling Conference in 2021

ATS Young Members

Although the **ATS** Young Members (ATSym) group was established under the steady hand and guidance of Dr Jurij Karlovšek in 2012, and continues to go from strength to strength, its precedent was set in 2004 when the ATS National Executive Committee decided it needed to, "add a young perspective to our activities going forward." Having conceived the idea of the David Sugden Young Engineers Writing Award in 2002, and selected the first winner, Dr Anmol Bedi in 2004, they subsequently created the Young Tunnelling Professional position on the National Executive Committee and elected Anmol to this new role, which he continued until 2007.

This year ATSym celebrates its 10th anniversary and is a well-established and much-admired group nationally and internationally. In Australia, the group provides a technical network for young professionals, engineers and students in the tunnelling and underground space industry and offers a platform for them to contribute their ideas and expertise to the profession. In the words of immediate past Chair, Keith Bannerman, ATSym also:

"...helps create a smooth pathway into the profession and increases our national capacity to build tunnels. There are few youngsters who dream of being a tunneller when they grow up. When we do outreach programs in schools, we'll always hear kids talking about wanting to build bridges, for example, but tunnelling is almost never a young person's aspiration. So, part of our activities focus on building that visibility and strengthening that voice for our profession to raise its profile and make sure we always have a healthy pipeline of talent coming into the industry."

Being part of the ATSym group offers significant opportunities to connect with likeminded people both in Australia and globally. Keith continues:

"One thing I find interesting when young tunnelling professionals get together at conferences and events, is the fire we have for our jobs. It's not uncommon to find us having impassioned debates about the most minute technical point. I remember being in Bergen, Norway for the 2017

ITA World Congress and standing outside, under the midnight sun, with young tunnellers from Switzerland, Norway, Brazil, Germany and Japan, and having a stand-up yelling match about the acceptable crack width in shotcrete! That's a pretty tiny thing to get worked up over, but it's wonderful to be around that enthusiasm and hear the diverse viewpoints from different parts of the world. That social element really helps drive the growth of this very small niche industry."

In recognition of the importance of making connections between the generations, ATSym has also hosted well attended events that facilitate this process. ATSym's Tunnelling across Generations event on Sydney Harbour in 2018, for example, attracted over 300 attendees. It is even a stated aim of the group to ensure, "that the knowledge of the collective 'grey haired' tunnelling community is able to be passed on to a new generation of professionals to ensure the collective improvement and development of the industry."

To continue our story, we will next hear from Jurij, whose energy and enthusiasm kick started the ATSym in 2012, followed by current ATSym Chair Brodie Aitchison.



Current ATSym Chair Brodie Aitchison speaking at the ATS Young Members Event at the ATS2020+1 Conference in Melbourne.

Immediate past ITAym Chair and now NSW Chapter Committee member Keith Bannerman (front row, second from the left), stands with the rest of the ITAym contingent at WTC2017 in Bergen, Norway.

GO UNDER ground

Supporting young tunnellers at home and overseas

Dr Jurij Karlovšek is a Deputy Director at Sustainable Infrastructure Research Hub (SIRH) and lecturer (Assistant Professor) in geotechnical engineering at The University of Queensland (UQ). He joined the ATS in 2009 and was the driving force behind establishing the ATS Young Members (ATSym) group, becoming the inaugural Chair between 2012 and 2018. Simultaneously, he co-founded the International Tunnelling Association Young Members (ITAYm) group and became the inaugural Chair of that too, between 2013 and 2018. These achievements no doubt underpinned his winning the ITA Young Tunneller of the Year Award in 2015. Jurij continues to be actively involved nationally in the Queensland ATS Chapter, and internationally as a founder and animator of the ITA Working Group 22: Information Modelling in Tunnelling.

“As part of my Bachelor of Civil Engineering degree, I conducted an international internship in Japan with a large construction company who build tunnels for bullet trains. This prompted me to explore my interest in geotechnical engineering so I sought an exchange program and my final year of studies brought me to Australia.

At Western Sydney University in 2007, I saw an advert for the ATS short tunnelling design course which was being held at UQ in Brisbane. It gave me a solid overview of the profession and convinced me that tunnelling was something I wanted to pursue. It is also where I met my future PhD advisor, Professor David Williams.

After graduating, I returned to my home country of Slovenia to look for a job. I found engineering and consulting company, Elea iC, and explicitly said, ‘I want to work for your tunnelling team.’ They gave me a job that same day. That’s what I tell my students now, if they can demonstrate their passion, it can be very easy to walk into the company they want to work for and get a job.

The first tunnel I worked on in Slovenia (Šentvid Tunnel) left a lifelong footprint in my career. It was part of a ring road being built around the capital city, Ljubljana, and my role was to design the tunnel support system for cross passages. To this day, I feel enormous pride that the tunnel will continue to serve its users for the next 100 plus years, long after I’m gone.



Bullet Train tunnelling; Jurij peeking through a TBM hatch in Japan.

I returned to Brisbane in 2009 to start my PhD and joined the ATS almost straight away. I met Mr Christophe Bragard, then Chair of the ATS

Queensland Chapter, who encouraged me to join the Queensland committee and we started discussing how to encourage more young tunnellers to join. I invited university colleagues and fellow students to ATS technical presentations and organised several ATS events on campus, but we saw it was hard for them to engage with the society in a meaningful way. If we wanted them to continue, we must create a specific young members networking platform.

Around the same time, I travelled to Geneva to present my PhD research at the World Tunnelling Congress (WTC) and met Mr Petr Salak, Chair of the already well-established British Tunnelling Society Young Members (BTSym) Group. He recommended we establish something similar in Australia so I pitched the idea to the ATS National Executive and travelled around Australia recruiting the young professionals who would lead the young members group in that state. ATSym officially started in 2012 in Queensland, and nationally in 2013 with me as the inaugural Chair.

Things were moving on the international front too. In 2013, I started the process to create an ITA Young Members (ITAYm) group and in 2014, Member Nations at the WTC Annual General Meeting, voted in favour of it, with initial support from Australia, the UK, Norway, Denmark and Canada. It was an honour to be elected as the inaugural Chair, supported by my great friends Petr Salak, Sindre Log, Nichole Boulton and Lasse Vester.

I’m really proud of helping create a pathway for future young professionals to not just feel more welcomed into the tunnelling community, but to be recognised as an integral part of the organisation, with valuable ideas and expertise to share. Young members will always be the future of the profession so it’s vital to support and inspire that pipeline of talent as much as possible. Particularly as we are living through the largest infrastructure boom ever recorded in Australia and the need to support the transition from tertiary education to young professionals is

“I’m really proud of helping create a pathway for future young professionals to not just feel more welcomed into the tunnelling community, but to be recognised as an integral part of the organisation, with valuable ideas and expertise to share.”

increasingly important.

Linking education and practice is one of my focus areas as an academic and I'm always encouraging young members to create the tools they would find useful. I also provide job opportunities, support research topics, and invite guest speakers to support students' interest in the field of tunnelling. I have authored, with the support of ATS President Dr Harry Asche, an Engineers Australia accredited University course, where we educate students and future tunnelling engineers in how to build underground structures. This course provides opportunities for industry to showcase their innovation and provide employment opportunities. In addition, students provide feedback on the ATS short design guide through their assignments which has created a successful positive feedback loop.

Having been involved with the ATS for more than a decade, I'm passionate about the next transition, particularly watching and helping the newly established sub groups: Diversity in Tunnelling and Tunnel Systems grow. The ATS has great momentum right now and I cannot wait to see how it evolves. Personally speaking, I have immersed myself in creating a new



Šentvid Tunnel; active and passive ground support, Slovenia.

research field at the UQ Sustainability Infrastructure Research Hub, where I lead the area of digitalisation for a sustainable infrastructure future. I have no doubt underground space usage is a

vital component to achieve these global goals and I am working closely with ITA President, Professor Arnold Dix, and ITA's Executive Council to integrate this research within the ITA family."

Q&A with ATS Young Members Chair - Brodie Aitchison

Since 2015, the ATS has ensured the voice of the next generation of tunnellers is heard at the national level through the appointment of an ATS Young Members' (ATSym) Representative who sits on the National Executive Committee. Brodie Aitchison was appointed as the third ATSym representative in 2021.

Brodie is a chartered civil engineer specialising in tunnels and underground spaces. He is an active member of the Queensland ATS committee and was a key member of the ATSym team developing the Tunnel Design Guideline. His key areas of interest and aspiration are to develop and implement innovative technologies with sustainable methods within the tunnelling industry.

How and when did you get involved with the ATS?

I joined in 2011 when I first got into tunnelling. The regular technical sessions at Spring Hill in Brisbane were one of the places I first got to see how great the organisation was in bringing people together. The events were always packed with really interesting speakers. In 2018, an opportunity came up to join the Queensland Committee and in 2021

I was voted in as the Young Member's Chair.

What made you decide to get so deeply involved?

The ATS is a very solid industry body and it offers great opportunities to be involved with the industry beyond the company you work for. There's opportunity to meet and work with industry experts and to really broaden

your outlook on tunnelling and open new doors.

What have been the main benefits?

Opportunity, growth and knowledge.

What got you into tunnelling in the first place?

Like most people I got into tunnelling by pure chance. I was looking for an interesting job out of uni and there wasn't much on offer in Adelaide at the time so I applied for a job in Brisbane as a civil engineer in a tunnelling department. I got a phone call mid-lecture one afternoon confirming I was successful and started a few months later. (Full disclosure, I knew very little about tunnelling and was very lucky to go straight onto a major project – Legacy Way – where some great tunnel engineers showed me the ropes.)

Why is the young members arm of the ATS important to the organisation as a whole?

Young members are the future. It's that simple. The enthusiasm and ideas that

can be brought up from the young members is key to driving the ATS forward and ensuring the organisation stays relevant.

How long will you stay in the position?

Probably a couple of years. Everything should have a time limit and I want to make sure others get the opportunity too.

What are you most personally proud of in terms of your contribution to the ATS?

My involvement with the young members side of things and particularly being on the working group that created the ATS Tunnel Design Guideline. This initiative was recognised for its contribution to industry in 2021 by winning the Engineers Australia President's Prize.

What do you hope to achieve in your time as Young Members' Chair?

I am working to get a strong young members' base across the country and to set us up as a sub group where we can plan and do our own things such as events and more initiatives like the design guide. I also want to make

"The ATS is a very solid industry body and it offers great opportunities to be involved with the industry beyond the company you work for. There's opportunity to meet and work with industry experts and to really broaden your outlook on tunnelling and open new doors."



sure our group is diverse, not only in gender but with a good representation of contractors, clients, designers and suppliers.

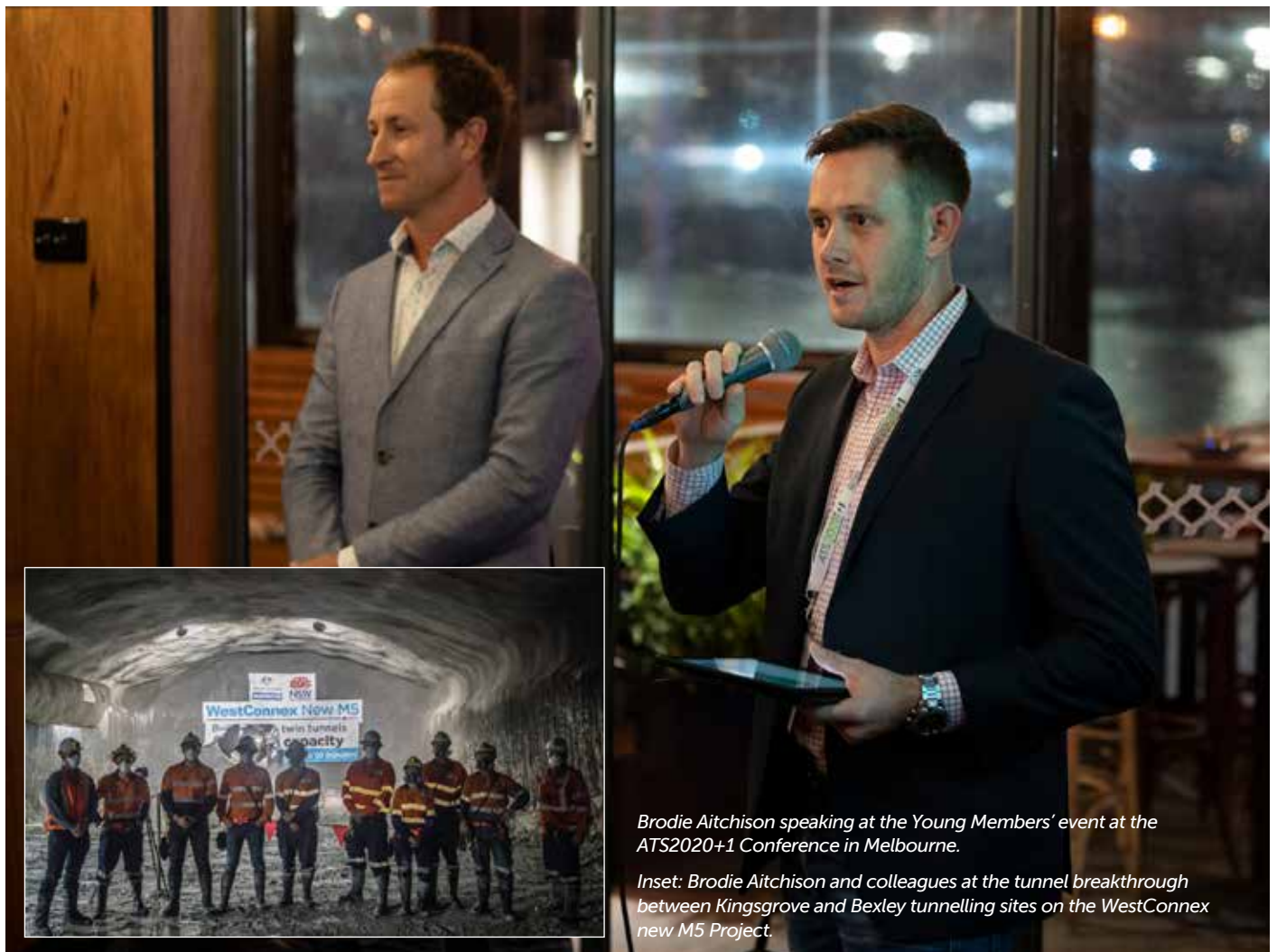
What's the most interesting project of your career and why?

Legacy Way for sure. I knew very little, and everything was new and exciting. The tunnel team was very small (five people), so I had the opportunity to look at almost everything across the job. Going to site really cemented it though:

12m diameter TBMs, drill and blast cross passages and working with specialist tunnelling contractors from overseas was an eye opener. I'll never forget going out to the Toowong cemetery at night and hearing the rumble from the machine just below the surface.

What role will ATSym play in the future of the organisation?

We will hopefully be able to bring new ideas and ways of reaching and staying engaged with the industry and universities.



Brodie Aitchison speaking at the Young Members' event at the ATS2020+1 Conference in Melbourne.

Inset: Brodie Aitchison and colleagues at the tunnel breakthrough between Kingsgrove and Bexley tunnelling sites on the WestConnex new M5 Project.

Diversity in tunnelling

Tunnelling is an overwhelmingly male profession, a fact that is reflected in ATS membership numbers. As of May 2022, the ATS had 768 members and only 10% of them were women.

In 2020, a group of progressive ATS members got together to try to figure out how to address this imbalance and, with the full support of the National Executive Committee, decided to create a Women in Tunnelling Sub Group.

The group hadn't been operational for long when they decided to broaden their agenda out. While encouraging more women into the profession was important, they felt a focus on gender alone was too limited. Other dimensions that have traditionally been missing from the profession needed to be recognised and embraced too, such as race, ethnicity, sexual orientation, socio-economic status, age, physical abilities and more.

Essentially, to function at its best, the tunnelling profession and associated disciplines need to reflect the attributes of the diverse Australian community it serves. As one of our storytellers, Sabrina Kost, will soon illustrate, diversity equates with flexibility and flexibility benefits everyone.

They decided to change the name to the Diversity in Tunnelling Sub Group which has the stated mission to:

"Promote, inspire and cultivate equality and inclusion in all sectors of the tunnelling industry through leadership, mentoring and engagement with the aim of attracting and retaining talented individuals."

Thanks in part to the booming industry and shortage of expertise, and in part to the industry-wide push for diversity, previously unheard-of roles are already starting to pop up, such as part time site engineers. There are also more women in senior roles who offer visible role models that encourage younger women to join the industry and, vitally, there are also senior men in industry who are lending their support to the diversity movement.

ATS's Diversity and Inclusion Protocol includes the following:

- A minimum 25% female representation in speakers/panellists at all ATS events;
- Integrating diversity and inclusion principles into all ATS events;
- Removing activities that hinder the diversity and inclusion principles of the ATS; and
- Establishing objectives for achieving improved diversity, including our commitment to have female representation on the National Executive of a minimum 25% by 2024.

"My mother was an incredibly successful, high-achieving, ambitious and pioneering PhD, which means I've never thought women less capable than men and why I'm keen to be part of the movement towards equality. I feel very lucky to have had that example and I feel it a great privilege to be able to throw my support behind the excellent women and men in the ATS who are so enthusiastically driving the Diversity in Tunnelling Sub Group forwards."

Harry Asche, ATS National Chair



Attendees of the Women in Tunnelling Breakfast during the ATS 2020+1 Conference

A positive shift in the industry – there is light at the end of the tunnel

Sabrina Kost is the Group Manager – Tunnels Sydney at SMEC. She started attending ATS events in 2008 when she moved to Australia from Switzerland, and has gradually become more involved in the organisation. Today she sits on the NSW Chapter Committee and is an active member of the Diversity in Tunnelling Sub Group.

“When it comes to attracting more talent into the tunnelling professions, being open to a more diverse range of people is key. The industry is certainly more aware of issues like the fact that many women, for example, drop out at a certain point because there is little allowance given to the commitments of having a family. Diversity relates directly to flexibility and flexibility benefits everyone – not just women. The days where managers or site personnel are expected to work full time, and sometimes on weekends,

must be relegated to the past and some amazing progress is currently being made in this space.

Some trials I’m aware of in the construction industry, for example, include trying out a five-day week and, for some consultants, a four-day week. In the context of an industry-wide talent and staff shortage, the focus has shifted to mental health and wellbeing. Fixing this will make the industry more attractive for everyone.

In my day-to-day job as a manager and technical expert, I am passionate about the positive impacts that tunnel projects can have on future societies. But I have also been exposed to all the

usual challenges and unconscious bias you might expect a young woman with a Swiss accent to face in such a male dominated environment and I’ve probably had to prove myself more than a male equivalent. But ultimately, it’s made me stronger and more resilient, and allowed me to become the underground expert and leader I have grown into and am proud to be today.

In the tunnelling industry specifically, I’ve been heartened to see the growing focus on attracting and retaining female talent in recent years. It’s great that ATS leadership has established the Diversity in Tunnelling Sub Group and I’m proud to be part of the energy, enthusiasm and ideas driving that agenda forward. The journey I have gone through personally has also encouraged me to mentor and coach younger female engineers, which is something I really care about, and we’ve already launched an ATS Mentoring Program. It feels like there is great momentum in the group right now and we have more initiatives planned.”

“It’s great that ATS leadership has established the Diversity in Tunnelling Sub Group and I’m proud to be part of the energy, enthusiasm and ideas driving that agenda forwards.”

Sabrina Kost at the Sydney Metro Martin Place Breakthrough in 2019

You can't be what you can't see

Iris Yim is a smart young Engineering Geologist working for Aurecon in Sydney. She's worked on tunnel projects in Hong Kong, on post-earthquake geology and seismic assessment projects in New Zealand and is now Sydney based, working on the proposed Western Harbour Tunnel. Iris is passionate about diversity in tunnelling and how it can promote better working relationships, motivate people and produce better outcomes.

"I joined the ATS in 2016 when I first moved to Australia to work on WestConnex because I wanted to meet people, get myself up to date on the industry, and try to understand how tunnelling was different to my work in Hong Kong and New Zealand. I started attending ATS workshops, presentations and the conference, and they were incredibly useful because the industries, and their approaches, are quite different. For example, we don't use roadheaders in Hong Kong at all. We mainly use drill and blast and TBMs because the rock, usually granite, is so much harder.

I really enjoy working in Australia, the industry here feels like a comfortable half way point between Hong Kong (which is so small, busy and highly populated that every available inch of land is used to its maximum value and we don't think twice about building tunnels) and New Zealand (which has a lot of land but a small population that seems to treasure their environment so much that most people don't mind driving for hours to get from A to B rather than installing a tunnel or bridge). In Australia the work is varied and interesting and tunnels are seen as a

good solution to urban problems. The work life balance is also great.

I decided to get more involved in the ATS in 2022 when they established the Diversity in Tunnelling Sub Group, which is a topic I'm really passionate about. I had suggested the ATS should start to properly recognise the contribution of women in the industry with the Women in Tunnelling Award two years previously, so it was wonderful the National Executive Committee decided to adopt this idea.

I actually think it could go even further by establishing awards that recognise the full diversity of the tunnelling industry because many different professions and people play a key role in tunnelling (for example geologists or systems engineers). It's really important to recognise and help everyone understand each other's roles more deeply, and perhaps change minds and behaviours for the better too."



Iris working on the Express Railway Link from Hong Kong to Beijing. Iris says this was a fascinating project in terms of its geology and was her first experience of grouting with high water inflow.

Tunnel Systems Sub Group

The Tunnel Systems Sub Group was conceived and established in 2021 after a group of ATS members got together to run a Tunnel Systems Workshop in 2019. The workshop consisted of six presentations and lots of vibrant discussions that highlighted a real need for the ATS, which mainly consists of professionals from the civil engineering disciplines (who build the shell of the tunnel), to create stronger links with tunnel systems engineers and associated professions (whose role it is to install the systems that operationalise the tunnel for whatever it's going to be used for). Today, the Tunnel Systems Sub Group's stated mission is to:

- Demonstrate the importance of tunnel systems and O&M (operations and maintenance);
- Showcase the expertise of the Australian Tunnel Systems / O&M community;
- Draw more people to the ATS community (beyond the civil engineering disciplines);
- Re-enforce the message that the ATS is more than excavation and tunnel lining; and
- Develop relationships with industry groups.

Cristian Biotto, a Principal of the Tunnel Systems team at Aurecon, has been a key leader in the establishment of the group. He says it is vitally important to have a forum where the group can share new ideas and lessons learnt with industry colleagues:

"Tunnel Systems sometimes gets bad press on major transport tunnel projects, with program overruns resulting from installation and commissioning issues. Tunnel systems are complex, and poor decisions and inadequate planning can have major impacts. It is important to share the good and bad to continue improving."

The group in action

An example of an area where the Tunnel Systems Sub Group is bringing the community together to lead change is the ATS Working Group developing proposals for improvements to Australian Standard 4825 (Tunnel Fire Safety).

Conrad Stacey (Director, Stacey Agnew Pty Ltd) is the Convenor of the Working Group which has brought together the various contributors to the industry including contractors, consultants, suppliers, emergency services and state government representatives.

Conrad knows the ATS can harness the breadth of experience in the tunnelling industry from those specifying requirements at the start of the project, to those operating the resultant constructed tunnels, and those responding to incidents:

"The practitioners that form the Working Group have worked on all transport tunnels being delivered over recent years, so there's no organisation better placed to develop a standard that represents current best practice."

ATS awards

Recognising the achievements of outstanding Australian tunnellers has been a staple activity of the ATS since the Tunnelling Achievement Award was introduced at the 4th Australian Tunnelling Conference in 1981. The inaugural winner was the late Alan Croxford, who was Chairman of the Melbourne and Metropolitan Board of Works from 1966 to his retirement in 1982. It was decided this award would be given out on a triennial basis at each national conference.

In 1993, it was unanimously agreed by the committee of the day that the fourth award would be made posthumously to Allen Neyland following his untimely death, and that, henceforth, the award would be known as the "Allen Neyland Tunnelling Achievement Award," in recognition of his service to AUCTA and the tunnelling and underground construction industry.

This was the organisation's sole award until 2002 when, inspired by the Harding Prize of the British Tunnelling Society, AUCTA decided to initiate The David Sugden Young Engineers Writing Award. This award was designed to encourage more younger members into the society and has been given annually ever since

Dr Anmol Bedi was nominated as the first recipient in 2004. (Anmol has since gone on to great things, as you can see from his contribution to this journal.)

In 2019, when the ATS was once again looking at how to boost its members in another underrepresented area - in this case a lack of female members - ATS Chair, Harry Asche, asked for ideas. A

young tunnel engineer called Iris Yim from Hong Kong (whose story you can also find in this edition) suggested the ATS initiate a new award for women tunnellers. The idea was embraced and the inaugural Women in Tunnelling Outstanding Achievement Award was initiated and presented to Diane Mather (also profiled in this journal), in 2021.



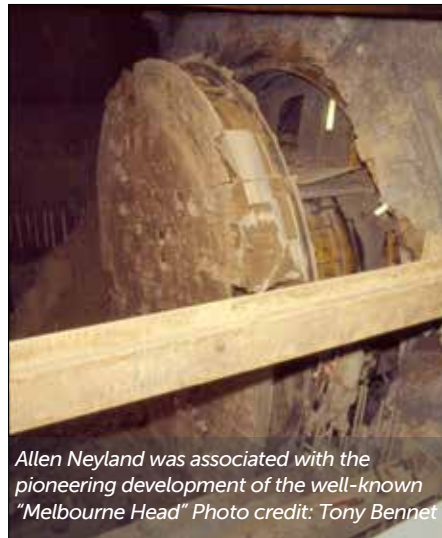
The Allen Neyland Tunnelling Achievement Award

Allen Neyland's contribution to tunnelling ranged from his early service in the Snowy Mountains Hydroelectric Scheme following graduation from the University of Melbourne in civil engineering. A subsequent career move took him to the H.E.C. at Poatina in Tasmania and the introduction of the first Robbins TBM to Australia.

He subsequently moved to the Melbourne and Metropolitan Board of Works on Section 3 of the South Eastern Trunk Sewer project, and was associated with the pioneering development of the well-known "Melbourne Head" of the Robbins Company to overcome stability problems in broken ground.

The latter part of his career was with Jacobs Associates and the Connell Consortium principally on the Melbourne Underground Rail Loop project, ultimately as Chief Construction Engineer, and advisor on other significant infrastructure projects such as:

- Sydney Harbour Tunnel;
- Brisbane Inner City Rail Tunnels;



Allen Neyland was associated with the pioneering development of the well-known "Melbourne Head" Photo credit: Tony Bennet

- Melbourne Water North Western Sewer;
- Melbourne Water Western Trunk Sewer; and
- Sydney Ocean Outfall Tunnels.

The trophy consists of a metal enamel plaque, symbolic of the achievements of Allen Neyland, mounted on a core of Victorian rock.

The David Sugden Young Engineers Writing Award

The late David Sugden was the driving force behind the successful design of mechanical full-face rock excavation machinery over a number of years, resulting in the forging of countless tunnels across the world.

He continually showed a commitment to innovation and design throughout his career, often custom making machinery to solve problems that arose and for which no existing devices were available or appropriate. As a result, David is listed as the inventor on over 40 patents. Beginning his career in 1938 as a Cadet Engineer with the Public Works Dept of Western Australia, he continued with several appointments at the Hydro-Electric Commission (HEC) of Tasmania. Whilst at the HEC, David was instrumental in introducing machine tunnelling to Australia. In 1967, he began a long and internationally recognised consultancy career. David received the Allen

Neyland Tunnelling Achievement Award in 1996, an Order of Australia in 2002, and the A.G.M. Michell Award for his outstanding contribution to Australian Mechanical Engineering in 2003. In 2002 the ATS initiated the David Sugden Award to encourage young engineers to develop the art of technical writing.



David Sugden's hand in the survival of the Robbins Company

Extract from Bill Bamford's Osaka Paper, written in 1994.

"... A young engineer named Griffiths, while returning from a holiday in Europe, visited the Oahe Dam site in South Dakota, and saw one of Jim Robbins' early machines in action. When he returned to Tasmania he wrote a memo suggesting that a TBM be considered for use in the Poatina Hydroelectric Scheme which about to be started. David Sugden was then working for the HEC as a mechanical engineer, and decided to do a cost/benefit analysis of the concept. He had a shaft sunk into the Permian mudstones through which the tailrace tunnel was to be constructed.

He constructed a miniature TBM, 500mm in diameter, and tried boring the mudstones, both with drag bits and with 70mm disc cutters. He concluded that the measured advance rates of up to 90mm/minute were promising, and calculated that the cost/benefit ratio was about 1/4. The HEC decided to seriously consider purchasing a TBM, and Ian Tulloch was sent on an overseas visit to inspect and assess all TBM manufacturers.

The HEC selected the Robbins Company, on the basis of their disc cutter experience, and placed an order. David Sugden went to the Robbins factory in Seattle, where he took an active role (which he has continued to the present time) in suggesting modifications to the previous machine configuration and principles. Innovations such as the floating gripper concept, used ever since, were directly attributable to his advice. He directed 3 phases of redesign and rebuilding of the machine when it was working in Tasmania.

At this time Jim Robbins, the founder of the Robbins Company, was killed in a plane crash. His young son Dick had just graduated from University with a Mining degree. He had not intended to go into the family business, but now suddenly found himself in charge of it. There were no orders visible, and he was starting the process of dismissing most of the work force and giving up the lease on the factory when the order from Tasmania came unexpectedly, "out of the blue".

Dick Robbins later said that he always had a soft spot for Australia, because that Tasmanian order saved the Robbins Company from folding up...."

The Women in Tunnelling Outstanding Achievement Award

As part of the activities of the Diversity in Tunnelling Sub Group the ATS established the Women in Tunnelling Outstanding Achievement Award in 2021 to recognise the contribution of women in the tunnelling industry. The award will be presented triennially at the Australasian Tunnelling Conference to a woman, "for their technical excellence and industry leadership in their chosen field" and who are "active in industry involvement, including promoting the role of women in the industry through role modelling, mentoring and/or advocacy to attract and retain women and girls in the field of tunnelling."

Inaugural winner - Diane Mathers

Diane Mathers (who is also profiled in this journal), was presented with the inaugural Women in Tunnelling Outstanding Achievement Award in 2021 in recognition of her extensive contribution to tunnelling and mining in Australia and internationally.

The award acknowledged Diane for her technical knowledge covering tunnelling and geotechnical issues, through to a management of tunnel designs and construction.

Diane said she was thrilled when she received the award at the Australasian Tunnelling Conference in Melbourne, particularly given the esteemed women also nominated.

"It's quite amazing, all together there were 25 nominees and quite a lot of those ladies I do know and I've worked with.

They're all pretty outstanding candidates and there are a lot of achievements there so it's very nice to be recognised by such a high calibre of people as well," she said.

"This award demonstrates that the ATS is recognising the need for inclusion and diversity to be foundational pieces of our future. I have travelled my own path to this award, not conforming to the classic tunnelling routes that are common within the industry. I challenge the ATS executive and, in particular, the ATS members and sponsors to bring diversity and inclusion to the society. These actions belong with all ATS members to drive this action and bring change by being involved and forging new paths that will shape a better and stronger ATS."



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Diane Mather sought out the ATS as soon as she moved from the UK to Australia in 2005. She had previously been involved in the British Tunnelling Society and was interested, on her arrival in Brisbane, to build her professional network and find interesting ways to maintain her Continued Professional Development (CPD). This she did (and then some). Rising through the ranks of the ATS, Diane became well known for her organisational abilities, passion for tunnelling and ability to petition for change. She has been a prominent advocate for many things including mentorship pathways for female engineers, being the voice of industry to the wider community and establishing new events and initiatives.



“The idea of pursuing a career in the underground industries began when I was growing up in Cornwall, England. There are a lot of mining features, like engine houses, dotted all over the landscape and two working tin mines very close to where I grew up. I knew people who worked in the mines and was fascinated with how it all worked. It was great to have the Camborne

School of Mines on my doorstep, a place renowned for engineering, mining engineering and earth sciences, and it gave me a good foundation in a lot of disciplines. When I graduated in 1998, there was a downturn in the UK mining industry so my first job was working on a storm water tunnelling project. After that I worked for the London Underground and then moved to Brisbane to work

on the Gold Coast waste water pipeline project. I have worked on several tunnelling projects since. Throughout my involvement with the ATS, I enjoyed working with colleagues in the Queensland Chapter and nationally to create high-quality events and excellent CPD opportunities for members from a variety of discipline areas, including non-engineers. The

Mt Coot-tha Quarry Day experience I organised alongside Alan Robertson is a particularly good example of this.

I love talking about tunnelling projects to the wider community too. Helping bring a broader understanding of what tunnelling is all about and the benefits it brings to communities is extremely important. I have a presentation I have been showcasing to various groups that describes the four major tunnelling projects currently active in Queensland. This includes schools, community groups, communities of practice, and other industry groups. I have also appeared on podcasts and local community radio to promote the Australian tunnelling and infrastructure industries.

Within the ATS, I helped establish the Diversity in Tunnelling Sub Group, and the Tunnel Systems Sub Group and have been active in supporting the ATS Short Courses and the young members to create the ATS Tunnel Design Guideline. I also represented the ATS with updates to

the Australian Standards AS4825 Tunnel Fire Safety Design and AS1726 Geological Site Investigations.

I am also very honoured to have been awarded the inaugural ATS Women in Tunnelling Outstanding Achievement Award in 2021 at the ATS National Conference. Deciding to pursue a career in tunnelling as a woman is not for the faint hearted and I am extremely lucky to have several fabulous supportive mentors including Alex de Aboitiz, Professor Arnold Dix, Conrad Stacey, Ed Taylor, Mark Percival and my PhD supervisor, Professor Bre-Anne Sainsbury.

I also find mentoring young engineers and graduates, particularly young women, very rewarding. It's wonderful to see them develop into more senior roles such as project managers, engineering managers and construction directors.

Career highlight

The WestConnex M4E tunnel project in Sydney is a definite highlight. The project includes 5.5km of tunnels and

around 7.5km of surface roads and I was working in the Aurecon Jacobs joint venture design team under Mark Percival and Troy Burton. The design team had a large scope of works to deliver under a tight program and the energy and spirits of the design team made this an exciting challenge.

This project is part of the wider WestConnex scope of projects that will transform the liveability of Sydney by taking cars and trucks off surface roads, easing congestion, and improving liveability for local communities. The project was complex with tunnels up to 34m wide and 8m high – some of the widest in Australia, at an average tunnel depth of 35m below the surface.

Later, I transitioned into the construction phase and enjoyed seeing the design we had created on paper come to life in construction. The project involved 28 roadheaders, making this the greatest number of roadheaders used on a single project anywhere in Australia."

Mt Coot-tha Quarry Day experience

Mt Coot-tha Quarry in Brisbane offers an interesting location to talk tunnelling due to its role in the Brisbane Legacy Way Tunnel project, which commenced in 2011. When designing Legacy Way Road Tunnel, the team spotted an opportunity to build an innovative underground conveyor to transport spoil directly from where Legacy Way was being excavated, taking it underneath the Brisbane Botanical Gardens, through to the Mount Coot-tha Quarry. This meant spoil could be removed from the construction site 24/7, making it incredibly efficient and eliminating the need for an estimated 96,000 truck movements on surrounding local roads.

As part of the 2015 ATS Design and Construction Short Course, the ATS Queensland Chapter organised a one-day practical workshop at Mt Coot-tha Quarry. This initiative was led enthusiastically by Alan Robertson who contacted colleagues at Brisbane City Council and several suppliers to contribute to the day. The support from the industry and suppliers was great and a live day of all things tunnelling was

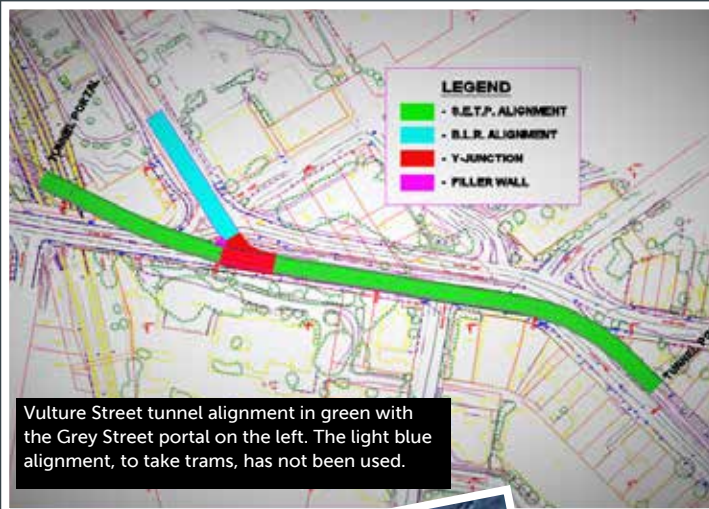
held in the quarry where delegates got to see firsthand the plant and equipment spoken about in the classroom.

The visit included exhibitor demonstrations from a variety of contractors, followed by an afternoon of technical presentations on a wide array of tunnelling-related topics including local geology; the synergies between tunnelling and quarry projects to transport

tunnel spoil; tunnel support design; shotcrete trialling; and a comprehensive rundown of the major tunnel infrastructure projects in the region at the time. The course was a great hit amongst ATS members and guests and feedback was very positive from the around 70 participants and 12 exhibitors who attended. By popular demand the workshop was held again in 2020.



SET 1B: South East Transit Project Busway Project Section 1 – Vulture Street Tunnel



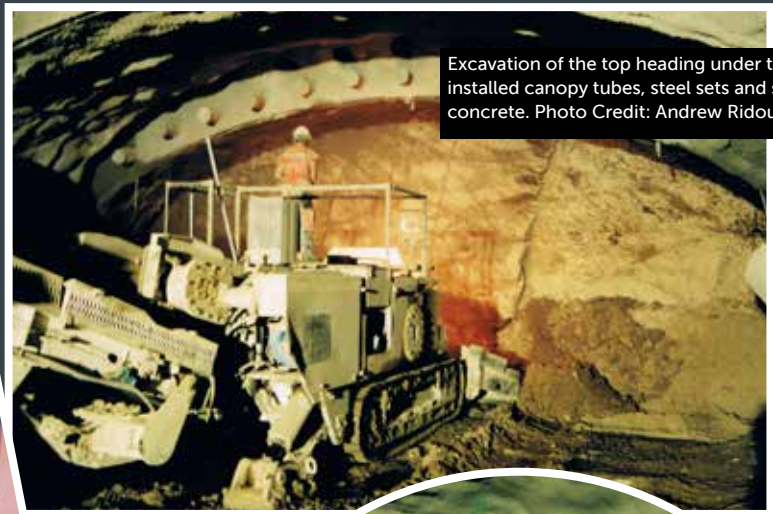
Vulture Street tunnel alignment in green with the Grey Street portal on the left. The light blue alignment, to take trams, has not been used.



Paurat roadheader mines the first metres of the tunnel under the train line from the Grey Street portal. Photo Credit: Andrew Ridout

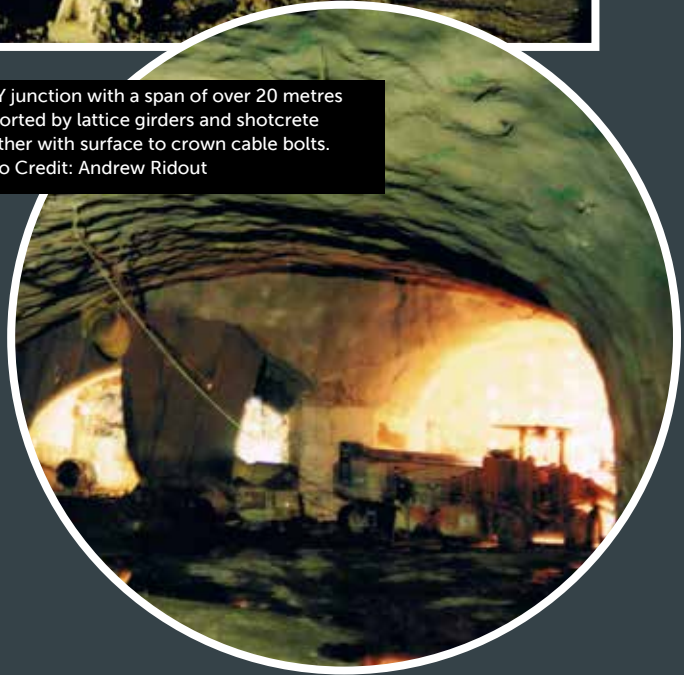


Concrete drift beams, either side of the tunnel for the first 50 metres under the railway, were installed to take the steel sets. The drifts were excavated with a Mitsui S65 and supported with fibreglass rockbolts. Photo Credit: Andrew Ridout



Excavation of the top heading under the already installed canopy tubes, steel sets and sprayed concrete. Photo Credit: Andrew Ridout

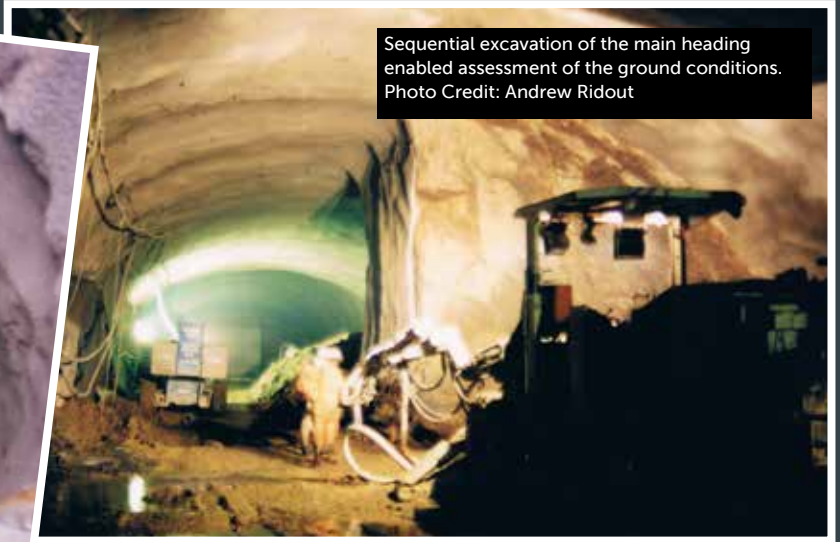
The Y junction with a span of over 20 metres supported by lattice girders and shotcrete together with surface to crown cable bolts. Photo Credit: Andrew Ridout



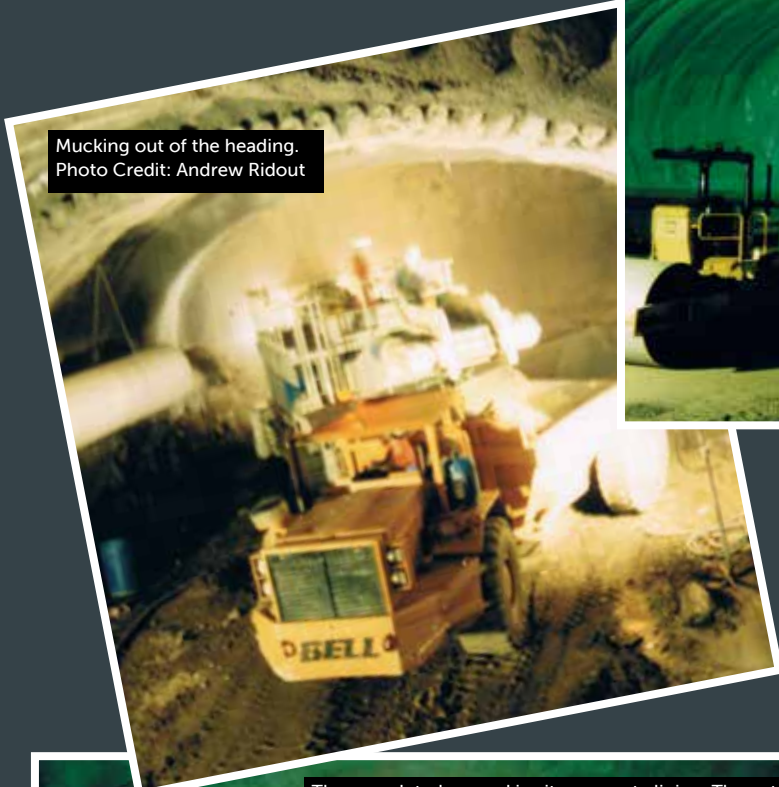
For more information on this project scan the QR code to access the following article: Buses driven underground - Tunnels and Tunnelling International September 2000



The Y Junction filler wall being poured out of the ground. Photo Credit: Andrew Ridout



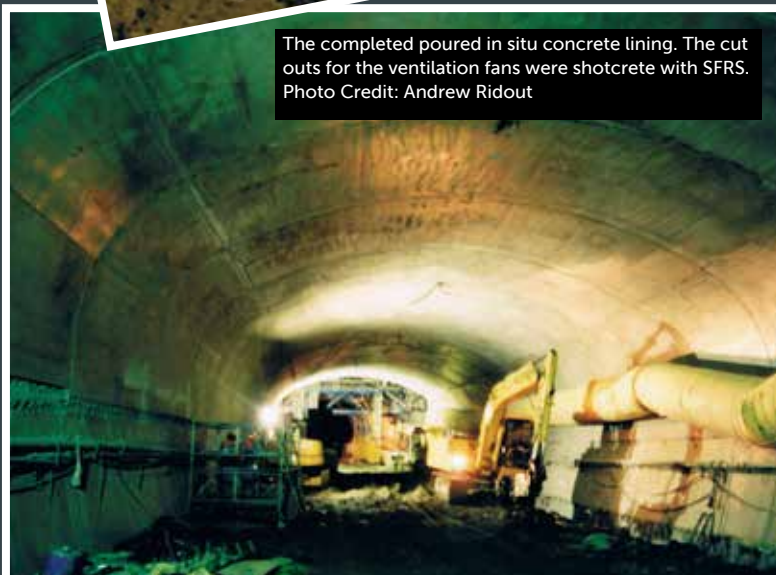
Sequential excavation of the main heading enabled assessment of the ground conditions. Photo Credit: Andrew Ridout



Mucking out of the heading. Photo Credit: Andrew Ridout



Fully tanked tunnel with sheet membrane awaiting the concrete final lining. Photo Credit: Andrew Ridout



The completed poured in situ concrete lining. The cut outs for the ventilation fans were shotcrete with SFRS. Photo Credit: Andrew Ridout

"SET 1B was one of my early projects which I look back on now and realise I learned so much in such a short tunnel. I learned how to assemble and operate a concrete lining arch form (from Stephen), which was an invaluable experience. Then there was sinking a filler wall shaft in Vulture St, amongst more electrical, comms, gas and God knows what other services known to mankind! I learned how to use the biggest Paurat roadheader for five minutes a day to excavate a few wheelbarrow loads, before embarking on two days of canopy tubes, lattice girders and shotcreting etc!"
Arran McGhie, Chief Operations Officer, GENEX POWER

"The design of the Vulture Street Tunnel as part of the South East Transit Project was my first tunnel project as a university graduate entering the workforce. It was fair to say I was hooked and I have been involved in tunnel projects ever since."
Tony Peglas, Principal, Tunnelling at Aurecon

Blast from the past

Before we launch into the next series of articles, in which we've commissioned experts to write about the history of tunnelling discipline areas and how they have evolved over the last 50 years (including contracts, safety, shotcrete, tunnel systems, rock cutting, grouting, geotech and support design) we thought you might enjoy a blast from the past. These short extracts below were mined from the rich seam of historical information that is the ATS (then AUCTA) journal. Both appeared in the July 1988 edition. In the first we'll hear a personal anecdote from the world-famous Allen Neyland, in the second we'll hear some record-breaking news.

EDITORIAL

[In the absence of our Editor, who is overseas, this editorial is contributed by the Chairman of AUCTA who, as you will see below, recently had something akin to a "born again" experience in the outback, an experience which has influenced this issue.]

As a student, forty years ago, I journeyed during vacation to the Zinc Corporation at Broken Hill for my first taste of underground development. This year, during a visit to two of our major mining fields, I travelled down the same shaft, probably in the same cage, but there the parallels stopped. Modern underground development and mining today is a far cry from what I saw in my youth, but the enthusiasm is as great and the technical innovations more exciting. Two such innovations seen were the Mobile Miner at MIM, Mt Isa and large diameter sequential raiseboring at ZC Mines, Broken Hill. Coincidentally, these two projects were also the subject of papers presented at the AusIMM NW Queensland Branch Underground Operators' Conference in June of this year.

Partly because of the above, in this issue we are focussing more than usual on Australia's great mining industry. As a civil engineer, I for one tend to get wrapped up in the philosophies related to design and construction of permanent structures — public utilities that must convey water, sewerage, trains or motor vehicles safely for a hundred years or more. In this milieu, one tends to forget that "out there" there is another philosophy, one that is directed to the production of the nation's wealth rather than servicing the metropolises.

So let us look at what is going on in a vigorous industry and, especially in this issue, its metalliferous sector. The two particularly interesting developments covered, the one in raise boring and the other in machine tunnelling, are presently peculiar solely to our mining fields, but they must have great potential in "civil" construction. One comes to this country after initial development in South Africa; the other is currently a US-Australian prototype development which, when completed, bids to be as significant an advance in machine design as were the introduction of the rotary TBM, the raiseborer and the roadheader.

Civil and Mining "tunnelling" must keep in touch and each will then benefit from the ensuing cross fertilisation. We hope that other similar articles touching on investigation, planning, design and construction matters will be contributed to future issues from both sectors.

Allen Neyland,
Chairman

THE MOBILE MINER AT MT ISA

The prototype Robbins Mobile Miner has just completed its second task at Mt Isa, a 570 metre long horizontal drive. This followed on the original 1150 metre long decline, which was the first application to a production task for this new concept in hard rock boring. Ground in both excavations was similar, being quartzite and greenstone. While some results from both excavations have been published, both the mine management and Robbins are being fairly guarded about recent performances. This is hardly surprising, bearing in mind the worldwide marketing potential for such a machine in both mining and civil fields in rock that is far too hard for conventional roadheaders. The joint venturers are reviewing the machine's performance in the second application with a view to determining the potential for further improvement in possible future applications. Another major metalliferous miner in NSW is said to be considering entering into similar R & D for a new model machine, presumably incorporating the lessons learned so far at the Isa.

This is heartening confirmation that private enterprise is willing to back its judgment in the potentially very risky and expensive business of developing new rock excavating equipment. It brings to mind that it was an Australian semi-governmental authority that, thirty years ago, was prepared to persevere with the early rotary TBM concept. The current R & D involvement of two of our major mining companies on a co-operative basis with an international machine manufacturer maintains the strong tradition of decisive Australian involvement in the practical development of world class hard rock boring with disc cutters.



TJ's Podcast Series

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Podcast Episode 4

In this "standards" themed episode, Professor Dix draws on almost 30 years global legal experience as a disaster investigator, lawyer and barrister with his candid insights and advice on empowering underground professionals in the proper use of standards and other common practices to manage personal/professional legal risks.

Please Visit: <https://soundcloud.com/tunnellingjournal>

Reflections of a career paralleling the 50 years of the ATS

By Dr Charles MacDonald

Coincidentally, my 50 years of work experience corresponds almost exactly with the 50 years of the existence of the ATS and this causes me to reflect on what has changed in the industry, either positively or negatively, over that period and what remains constant.

During these 50 years I have worked in a number of countries including the UK, Far East (Hong Kong, Singapore and Philippines), Saudi Arabia and Australia. I have also been employed in all sectors of the industry including client, contractor, consultant and academia which I believe gives me a broad career base on which to make such a reflection.

Whilst not all of my career has been in underground works, it has been the predominant field of my professional life for the last 30 years, primarily in tunnelling associated with road and rail transport, but also other applications such as hydroelectric and utility tunnels (drainage/sewerage and power transmission).

The range of tunnelling projects I have had a significant involvement in the planning, design and delivery of include the Melbourne City Link, the whole WestConnex Scheme in Sydney and the Brisbane Airport Link. In more recent times I have provided peer review services on such projects as the Melbourne Metro and Melbourne Rail Loop projects

The first and most obvious change from the status of tunnelling 50 years ago is that an increasing amount of infrastructure including road, rail and utilities power, water and telecommunications, is now being located in tunnels, even though placing such facilities underground is significantly more expensive than equivalent infrastructure located above ground. This is a trend that has occurred in many countries around the world but it is very strongly illustrated by the adoption of an almost totally underground solution for the \$16 billion WestConnex urban motorway scheme in Sydney, supporting the proposition that tunnelling is enjoying a golden age.

Modern equipment and techniques make tunnelling more cost effective than it has ever been. This combined with increasing concern from the



community about the adverse consequences of above ground solutions means that the underground alternative is now often seen as the only acceptable way forward. That said, underground solutions are not without potential impact particularly in relation to ventilation, air quality, fire and life safety, dewatering and ground settlement issues.

The technical developments over that period have been very substantial.

'Uncertainty is a feature that is unavoidable in tunnelling, but it can be understood and controlled so that it does not cause damaging risk.'

This includes TBM and roadheader technology, blasting techniques, numerical analysis software available to refine both temporary and permanent design, shotcreting and grouting techniques plus many other advances in plant and equipment generally. Such technological developments continue to evolve at a rapid pace and the ongoing evolution of automated and robotic technologies will greatly assist in the development of underground space in a way that was very difficult and prohibitively expensive in the past.

I now turn to what has not radically advanced over this period and arguably even receded. As a now 'mature' member of the tunnelling industry I have been around long enough to



have had the pleasure and privilege to meet and briefly work with Sir Alan Muir Wood who, in 1974, was the founding president of the International Tunnelling Association, an organisation which now has some 75 member countries globally, with Australia represented by the ATS.

Sir Alan had a very clear view of how the management of risks in tunnelling should be addressed and this is captured in the following quote:

Despite this statement by one of the most respected forebearers of our industry, the management and allocation of risk and uncertainty on major tunnelling projects, particularly in Australia, remains a matter which is often poorly addressed.

Reference to any text on risk allocation will inevitably uncover the principle that 'the risks in a project should be apportioned to those stakeholders who can best manage them.' Whilst it seems that this maxim appears to be universally recognised it is sadly rarely practised, primarily because it is often considered 'easier' to pass all risks on to others rather than adequately analyse how particular risks can be better managed. Several developments have taken place in the last fifty years in the evolution of alternative delivery

models for major infrastructure projects including tunnels. However, the manner in which risk allocation, as opposed to risk management, has been addressed has not, with a few notable exceptions, genuinely advanced particularly in relation to tunnelling projects. In fact, the view can be formed that in many major projects the allocation of risk is less fair and equitable than it was fifty years ago. This is a topic taken up in more detail in another paper (Dix, MacDonald) in this copy of the Journal.

The nature of tunnel projects i.e., complex engineering challenges in uncertain ground conditions in tight time frames, lend themselves to the greater adoption of more collaborative procurement models which provide fairer and more equitable allocation of risks, including unforeseen ground conditions, between the contract parties. Much could be gained in this area by considering and hopefully adopting internationally developed contract forms that specifically address the particular circumstances of underground works rather than the continued adoption of unique bespoke contracts for each individual project.

Concluding on a more positive note: In my view, the challenge, complexity

and at times heroic scale of major underground works has attracted many of the brightest engineering minds and innovative constructors over the years. That tradition appears to endure with the industry continuing to attract many highly talented younger members of the profession.

There is every indication that there will be an increasing number of upcoming major infrastructure projects, particularly road and rail, which will require tunnelling solutions.

It is also evident that significant progress has been made in recent years in improving communications between clients and those parties tendering for and delivering such major projects. This is apparent in the much more open dialogue between the parties during the tendering process and a general acceptance that more substantial site investigations should be undertaken by the client before going to the market to procure delivery of a project.

There are also indications that more enlightened clients are becoming open to the adoption of fairer and more equitable procurement models/ contracts which will deliver better value for money to the whole community.



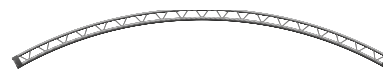
DSI Underground is proud to be supporting the ATS and be associated with the Australian tunnelling and construction industry. Our success comes from wide ranging projects providing proven solutions that reinforce progress underground. Our products keep workers safe. Our reliability helps engineers plan ahead, and our technical expertise keeps tunnels advancing efficiently to bring benefits to everyone.



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50 years of health and safety in tunnelling

By Wayne Bradford, Health and Safety Professional - Retired



Wayne Bradford

My Father, Grandfather and Great-Grandfather worked in the mines so it felt inevitable that I would also work in the mining industry. In 1981 I completed my Associate Diploma in Surveying and joined Mount Isa Mines as a Surveyor. After working at Mount Isa for seven years I began a career in contract mining with Redpath Australia (formerly EROC Pty Ltd), a major underground mining and civil contractor, on projects such as the Hazelbrook sewer tunnel and the Prospect to Pipehead water tunnel.

It was with Redpath that I began my career in Health, Safety, Environment and Quality (HSEQ) with my first project in this role being the M2 road tunnels project in Sydney. I was the project's Quality Assurance and Safety Representative until completion in 1996. The project was completed ahead of schedule and with no lost time injuries (LTI's). Following this site-based role, I accepted a corporate position as HSEQ Manager with Redpath at their Brisbane Headquarters. Over many years I developed project specific safety plans, standards, inductions and training packages and procedures for Redpath's mining clients, including BHP and Newcrest, as well as civil projects, including the SET 1B Busway tunnel and the S1 sewer tunnel in Brisbane.

My experience on the ground, or "at the face," has given me a front seat to the changes in health and safety in this industry over the last 40 years. The following is a brief overview of some of the most important factors influencing safety, and how they have changed.

The original Snowy Hydro Scheme had 121 fatalities over its 25-year construction period from the 1950's to the 1970's (or

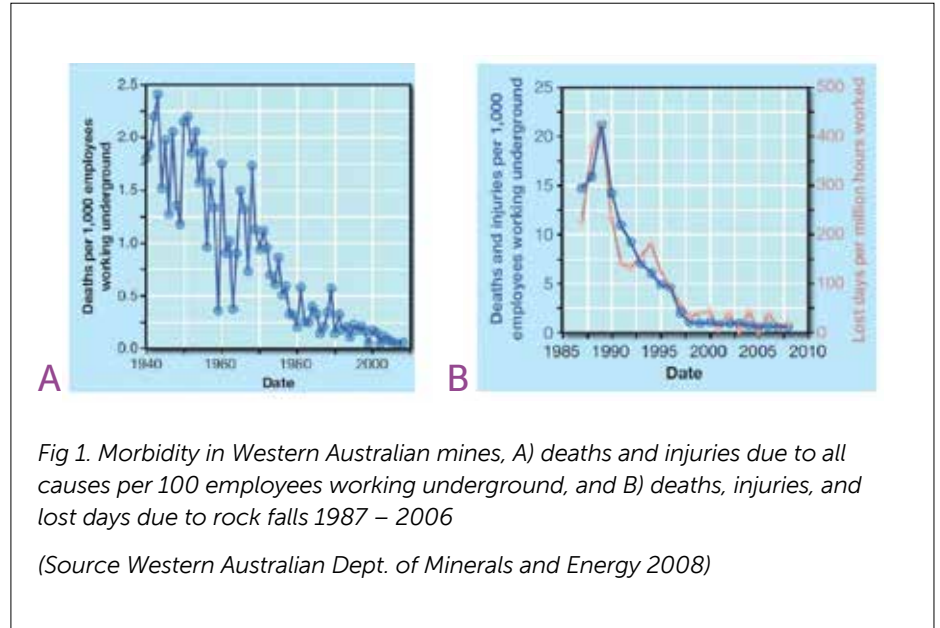


Fig 1. Morbidity in Western Australian mines, A) deaths and injuries due to all causes per 100 employees working underground, and B) deaths, injuries, and lost days due to rock falls 1987 – 2006

(Source Western Australian Dept. of Minerals and Energy 2008)

4.84 per annum) reflecting the industry's safety attitude at this time. The Snowy consisted of approximately 90 miles of tunnels so the expression "a fatality per mile" was seen as "OK." Thankfully that mindset has completely disappeared and replaced with "there is no acceptable level of fatalities or injury" in the workplace.

Although not a direct comparison, a stark decline is revealed by the number of fatalities in WA mines since the 1960's. The workplace has doubtlessly changed for the better in terms of worker security.

The reduction in fatalities, a key, but imperfect metric for safety performance across the broader underground industry, is due to the increased attention to the following key areas.

- The implementation of safe systems of work (i.e., risk management supported by new technology)
- Increased workers compensation premiums for recidivist employers
- Stronger enabling type workplace legislation
- Implementation of effective safety management systems
- Fitness for work reforms
- Taking a behaviour-based approach.

These changes have greatly improved worker safety in the Tunnelling industry.

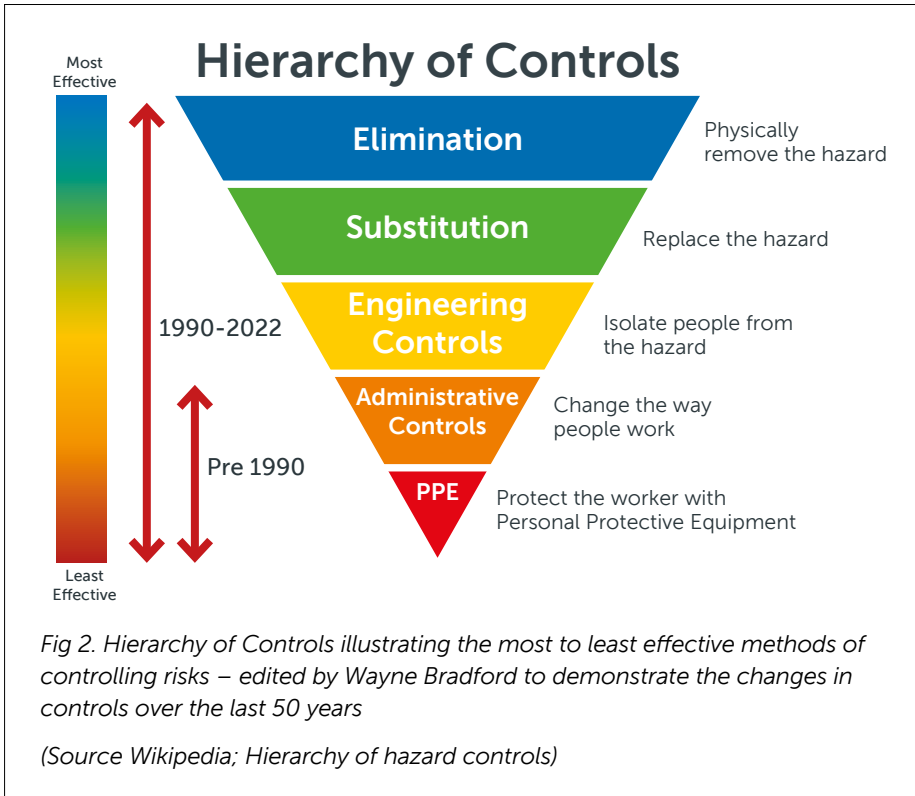
Risk management

This crucial aspect of Health and Safety only really took shape in earnest in the mid 90's. Prior to this, risk management was a relatively unstructured exercise undertaken in a manner that was largely at the discretion of the relevant project management and focussed only on administrative controls and Personal Protective Equipment (PPE). Risk management is about identifying and managing risks to individuals onsite by employing strategies to combat those risks with the aim of keeping people safe.

The "pyramid" or hierarchy of controls is one strategy used to keep the mind focussed on highest risks using mitigation techniques to always strive for a control that is "higher" on the pyramid. I remember running two-day project wide risk assessments with clients, with a specialist assessor proving invaluable to get people to focus on the risks. These meetings also involved addressing the risks at the "highest" possible level. Undertaking a risk assessment in another country prior to delivery of a machine has also assisted with the question, "what risks are we buying?"

New technology – risk management

New technology in the mid 90's played a significant role in mitigating some



of these risks by taking the preferred “higher” level approach to risk control. Take, for example, the use of fibre reinforced shotcrete that negated having to install wire welded mesh under unsupported ground, plus remote-controlled equipment, such as shotcrete rigs and bolters, that keep the operator in a safe location while the activity is being undertaken. These are examples of “engineering” controls that are preferred over “lower” levels of risk management that existed prior to the 90’s. The author recognises that PPE is the last resort (or “lowest” level) in risk management, however in some cases it is not possible to use a more effective method of risk control such as elimination or substitution.

PPE has not only improved significantly in the last 50 years but is also readily available and recognised by all as a benefit. Whereas a safety helmet and safety boots were always seen as the requirement to access a project site, today these must be supplemented, at a minimum, with reflective clothing, safety glasses, gloves, and masks which are mandatory on most sites. Modern PPE products have led to increased uptake and reduced reluctance in workers who find the lighter, more efficient, dust masks, stylish safety glasses and more tactile gloves make for a more comfortable and less restrictive workday.

Legislation and Workers Compensation – the stick!

In the early 2000’s experienced based premiums (for workers compensation)

were introduced by insurers to provide project managers and owners with the real cost of treating workers’ injuries. Prior to this, an injury was seen as just another incident irrespective of its magnitude, and insurers determined an appropriate premium across the industry for all businesses. This gave no incentive for contractors as there was no mechanism to reduce premiums. Experienced based premiums identified the cost of each injury and the total cost per business each year. This encouraged owners and contractors alike to review safety performance to reduce their premium and gain a competitive edge (noting that in some states this broad-brush system still exists, but is seen as regressive.)

Further, until the 2010’s, systems were lacking for workers to report injuries that occurred at work, and workers were not encouraged to report injuries and in some cases were actively discouraged. In recent times workers are more aware of their obligations than was the case in the 1970’s and 80’s and therefore now report their injuries and seek medical treatment more frequently when injured at work. In turn this results in an increase in experience-based premiums which further encourages owners to take action to improve safety performance in a contracting environment. Having a 1 or 2% reduction in your premium could provide a substantial benefit in a competitive tender.

Other legislative reforms in the safety arena have increased the onus on directors and managers at the highest

levels of an organisation by making them personally accountable for safety performance on the ground. Whereas, previously, safety was considered an individual’s responsibility, now directors and managers face the prospect of incarceration and large personal fines.

Safety management systems

During the 1990’s most companies in our industry were induced into implementing a Safety Management System (SMS). Many implemented “off the shelf” systems that bore little resemblance to their business and were essentially “window dressing.” 4 STARS is a well-known safety package which, even if attained, did not necessarily mean that a strong safety culture existed, but arguably misled management into believing so.

Today, SMS’s are where they should be, a tool to manage safety and not the “be all and end all” of safety performance. With the advent of robust handheld computer devices suitable for use in the tunnel we have seen pre-start checks, hazard observations, training material and safe work statements to name but a few, being input in the tunnel. Therefore, the worker is more in tune with outcomes than the SMS Management. They can analyse awareness, compliance and even the quality of compliance with handheld devices automatically updating systems from within the tunnel or upon exit from the tunnel.

Safety management systems – new technology

As mentioned above, new technologies have enabled the identification and mitigation of key risk factors in the workplace. The management of ground conditions, including its support and its installation, is the number one improvement over the last 50 years - so much so that work is NOT permitted under unsupported ground today. The management of ground conditions is now an integral part of any tunnelling SMS.

Historically, in my early experience, work at the face was all about “getting the metres.” I can recall on a couple of occasions being called up by the superintendent to see if the survey pegs had been installed for the next cut - to which I said yes! Of course, this was immediately after a blast and no mucking out or ground support had taken place. This meant the survey pegs had fallen to the ground due to rockfalls in a location that I had been earlier in the day. That mindset by senior leaders and the worker does not exist today.

Today access to the tunnel face is highly controlled. Strictly no access beyond the roadheader or bolter cabin



PPE has not only improved significantly in the last 50 years but is also readily available and recognised by all as a benefit.

until some initial support has been installed which usually involves a sealing layer of fibre reinforced shotcrete sprayed by remote equipment and rockbolts. This strict procedure alone has significantly improved workers safety and provides an example of the SMS in action.

The installation of the concrete linings in a TBM drive is undertaken by modern hi-tech remote suction equipment that keeps workers well away, a big difference to the manual systems used in the 80's and 90's and a further example of SMS's operating as they should.

Communications

Toolbox meetings have been the mainstay of communication between management and workers. Prior to the mid 90's these were mostly at the discretion of the site Project Manager and their own attitude and experience towards safety initiatives. Today they are an integral part of an SMS.

Nearly always there was something that resembled a toolbox meeting on a weekly basis but this has now evolved to a daily and/or weekly and/or monthly meeting dependent on the project site. These meetings are meant to improve two-way communication between management and workers, however, early on, worker's input was limited due to the endemic "top down" management

style of the 1970's and 1980's. As workers became more empowered, this two-way communication improved. Systems like PASS (Positive Attitude Safety System) have helped encourage this communication with standard formats etc.

Companies have refined the toolbox meeting's content to embrace a more holistic view of the worker's welfare. For example, topics for toolbox meetings or safety information sessions would be scheduled throughout the year with appropriate topics such as heat management in summer and/or alcohol awareness around the holidays. Subjects covered today do not just cover the workplace but range from cancer prevention to mental health and general wellbeing.

Fitness for work

Fitness for work means that an individual is in a state (physical, mental and emotional) to be able to perform their work competently and in a manner which does not endanger the health and safety of themselves or others. Mostly this was covered by a pre-start medical at the beginning of the job but today there is ongoing monitoring, sometimes as a daily occurrence. For example, on most tunnelling projects, entry to site, either by workers or visitors, is almost always predicated on a breathalyser test to

make sure that persons are not over the legal limit. On other projects this can be accompanied by random drug testing. The penalties for being over the limit are severe including instant dismissal. This was unheard of for most of the last 50 years when the culture of miners/tunnellers was to "work hard and play hard."

The implementation of these kinds of controls has seen a wider positive cultural change on the workers attitude towards these substances and is in keeping with society's broader view of a healthier lifestyle. Although it should be noted that anecdotal evidence indicates that there is a move from easily detectable alcohol/THC to "party drugs" that move through the body quicker and are less likely to be detected by these controls.

Behaviour based safety

Behaviour based safety is a proactive approach on increasing safe behaviour in a workplace. This approach focuses on reducing hazards, risks, and incidents by observing the behaviour of a person and determining what follows when this behaviour occurs. It involves analysing the consequences of a particular behaviour and providing proper reinforcement for a desired behaviour. This approach, whilst in its infancy, will certainly make a difference in the tunnelling industry. Whilst tunnellers

work as a crew, they perform many tasks as individuals and therefore any reinforcement by an observer (objective observer) on how the task was completed can only be a benefit. It has been my experience that the conversation generated may be the only personal interaction the worker may have had with a member of management.

Conclusion

It is sobering to think there are still workers being killed underground every year. Tunnellers now face a new set of challenges including pneumoconiosis (not new, but a disease that will come to the fore) mental health and a pandemic thrown in just for good measure, but I am sure the lessons learnt over the past 40 years have allowed management to adapt quickly and we will continue to see safer workplaces.

For the time I have spent in this industry, and particularly my time in the area of health and safety, I am heartened by the development and uptake of safety improvement in general. Workplace legislation, the threat of stiff penalties and the cost of injuries is balanced by a genuine mindset by all parties that ultimately want to see workers come to work and, then, GO HOME.



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Case study on silica dust

By Kate Cole, OAM, Engineer, Certified Occupational Hygienist



Kate Cole

Along with many other areas of tunnel construction, health and safety has significantly improved over the last 50 years. While my experience in tunnelling only extends to the last decade or so, I have enjoyed listening to the numerous tales told to me by the tunnelling greats of "how it used to be."

Tales of not being able to see fellow workers, simply because there was too much dust, or accounts from experienced supervisors on how impressed they are now, "in comparison to back then," happen quite a bit. So, to celebrate 50 years of health and safety, I'm reflecting on the work that was done by the ATS to address the elephant in the room that was silicosis and how, through a collaborative approach, we changed the way we proactively manage this ongoing risk in our industry.

It was at the ATS Conference in 2017 where we held an initial "Silica in Tunnelling Workshop." This brought together major tunnel projects alongside the health and safety regulator to understand if improving silica dust control could be achieved through a strengthened all-industry approach. The workshop was attended by leaders from both client and contractor organisations, along with representatives from SafeWork NSW. The overwhelming feedback was that addressing this was critical to the longevity of our industry.

At that workshop we agreed to create the NSW Air Quality Working Group (AQWG) so we could continue to collaborate and improve awareness and performance across our industry.

Collaboration with industry stakeholders is an essential part of raising awareness of the important issue of silica dust control, but also to enable effective strategies to be developed that are practical and a positive step forward. Over the period of 12-months, the AQWG focused on sharing information to address the challenges associated with controlling silica dust and producing a much needed body of reference material that previously did not exist in the tunnel construction industry's body of knowledge.

The valuable information produced included standardised, yet practical awareness material that could be effectively delivered during toolbox talks and tunnel inductions. Higher-level business processes associated with the tunnel construction life cycle were also addressed, so the risk of silica dust exposure could be effectively considered by client organisations during project planning and design. Numerous case studies on engineering controls were developed, including those on ventilation scrubber systems, portal misting systems and Roadheader cabin air filtration, in addition to general information on ventilation.

The need for a consistent approach for the performance of health monitoring of tunnel workers was identified as a key challenge, including improving the methods applied to determine which workers are required to participate

in crystalline silica health assessment activities. Therefore, material was produced to address this gap.

The need for a standardised and consistent approach for personal exposure monitoring, including the methods applied to sampling personal silica dust exposure concentrations was also addressed.

Information was provided on the effective use of respiratory protection and the limitations of use, including the need to be clean shaven; and case studies of practical engineering controls were collated that had been applied at tunnel construction projects to reduce silica dust exposure.

The ATS is a strong proponent of the importance of health and safety in the tunnelling sector and took a proactive approach to this issue through leveraging the strong experience of our membership and worked to produce a much-needed body of knowledge to support our ever-growing industry. The ATS formally launched the new body of knowledge in Sydney in February 2019, with the information still freely available on the ATS website.

The impact of the work of the AQWG has been significant. Later that same year in 2019 it was recognised by the International Tunnelling Association 2019 through being awarded "Safety Initiative of the Year". Fast forward to this year, and I've been reunited with many original members of the AQWG as we are part of the Advisory Committee established by SafeWork NSW to review the Tunnels Under Construction Code of Practice. The information we produced is helping to inform that improved Code.

The resources mentioned in this case study are freely available here:
<http://www.ats.org.au/resources/working-group-papers/>



The final meeting of the Air Quality Working Group, November 2018

Safety matters

By Dallas Adams, founder of DC Adams Group - Why Safety Matters

When it comes to safety in tunnelling, I believe it's important to look back and see how far we've come and the best way to relive the past is through storytelling.

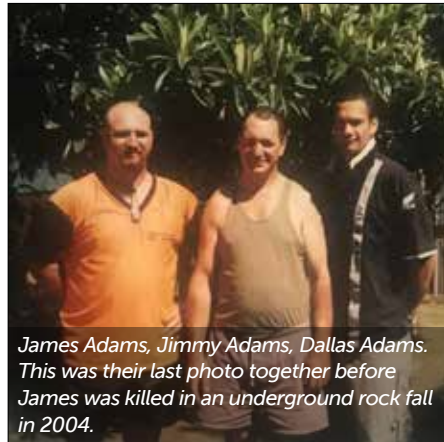
You could say that tunnelling is in my DNA. My family is originally from New Zealand and my grandfather, Jimmy Senior, worked in the industry for over 20 years and my father, Jimmy, notched up 46 years working as a handheld tunneller in both New Zealand and Australia. My brother, uncles, cousins and myself have all spent years in the underground mining and tunnelling industries.

Tragically, I lost my father when he was seriously hurt on the Sydney North Connex project in 2017. With his passing so, too, we lose his stories. This is why I travel the country offering my presentation, Why Safety Matters, and started my Podcast, Let's talk tunnelling. It is my intention that these platforms help these important stories live on, perhaps even for generations.

Being the son of an old-school tunneller (when safety was relaxed and PPE unheard of), my older brother (13) and I (10) would often head to work with dad over the weekend. We'd help him charge up the drill holes, extend services or hand him timbers for erecting steel sets.

I enjoyed these things, but the best part of the day was listening to my brother and father talking on the car ride home. Dad would explain how the ground conditions could change and how you could pick up on it by listening for a drummy sound. I can recall him telling me about how the hand-held drilling (air legging) sound of the steel drill rod would change when drilling through different layers. He also described how important it was to monitor the colour of return drill water, which indicated soil contents and depths of what's above and ahead. He would explain how ground support was vital. People often forgot about doing those little things. Like making sure their holes are straight and keeping their dome plate centred for the rock bolt nut, so the bolt is secured to full strength.

I remember seeing my father at the face of the tunnel after explosives had just detonated. He walked in right after a blast to check the cut, wearing only a wet rag over his mouth and nose.



James Adams, Jimmy Adams, Dallas Adams. This was their last photo together before James was killed in an underground rock fall in 2004.

This was his way of creating a form of respiratory control for the dust and fumes created by the blast and provides a huge contrast to the awareness of today, where proper ventilation and wearing dust masks are paramount to staying healthy.

My father had plenty of first-hand experience of how the industry changed, particularly as regards to safety. For example, he talked about operating handheld drill equipment and manually charging explosives in the drill and blast method; he talked about hand scaling, hand bolting and meshing before using single and double boom jumbo drill rigs; right through to TBM tunnelling where there is no exposure to the rock due to shields and precast segments being erected.

My father's method of teaching was handed down from those before him. That kind of on-the-job training was commonly used before the start of modern onboarding, Cert's, Qual's and VOC's. The processes are still similar, but the teaching methods more advanced.



Jimmy Adams admiring his work in the Cromwell Gorge drainage tunnel, Clyde Dam Hydro Scheme, New Zealand.

When people ask me why I continue to work in tunnelling after experiencing the loss of two family members (my brother also tragically died, in 2004, from a tunnelling accident), I say it is because I know safety has come a long way from when I first started. I also tell people it's a real pleasure to be a part of such unique projects that are built for the betterment of the greater community.

For more information regarding my organisation "Why Safety Matters" go to www.whysafetymatters.com.au

Moe mai raa e Te Rangatira e kore koe e warewaretta (Rest in peace our leader, You will never be forgotten)

Dark and dirty all around
It takes a special person to work underground
When things seem tough it doesn't take much
To lure them into earning big bucks
Light at the end can be a journey for all
Working together standing proud and tall
Starting can be daunting and a timely process
Finding your niche in a team is positive progress
The speed of the process comes with time
Working together is what we must find
Can it be done safely by eliminating the risks
So we all go home to our loved ones no less

50 years of contracts

To review 50 years of contracts in tunnelling, ITA President Professor Arnold Dix and long-time ATS member Dr Charles MacDonald review the 1974 classic tunnelling paper: *Contract Practices for Underground Construction* by T.R Kuesel. As you will see from their analysis below, they draw the conclusion that in the intervening 50-odd years, when it comes to contracting practices, we have done little and learned less.

The author

In 1974, at the time of publishing his paper, the late Thomas R. Kuesel was a Partner at Parsons, Brinkerhoff, Quade and Douglas in New York. A world recognised tunnel engineer, Kuesel designed over 140 tunnel projects across

six continents during his lifetime. He was a co-editor of the Tunnel Engineering Handbook, a standard reference for design and construction used worldwide, and published more than 60 technical articles on tunnels, structures and contracting practices.

The original summary

SUMMARY. Disputes and unnecessary costs attendant on construction of underground works may be minimized by careful consideration of pre-contract construction planning, the interaction of site conditions with design and construction, special handling of insurance, special forms of contract and of contractor compensation, and the manner of contract administration. A special report by the U. S. National Committee on Tunneling Technology gives guidelines for improved contracting practices for underground construction.

The analysis

Australia has an entrenched claims culture based upon belligerent risk allocation, creative claims formulation, aggressive litigation and messy political interventions. This is despite the existence of mature alternative contracting options from reputable sources such as FIDIC (International Federation of Consulting Engineers) and ICE (Institution of Civil Engineers in the UK), as well as numerous examples of alternative dispute mechanism frameworks which are available but generally dismissed.

Given the existence of internationally established options for mature informed contract management, it is surprising and certainly disappointing that Australian contracts for major tunnelling projects are invariably bespoke creations of such complexity that unique teams of people are required to draft, interpret and manage each one of them. The Australian contract is a virtual project of its own. Alternative dispute mechanisms and well-articulated mechanisms for managing differences of expert opinion and agreement of fact in modern contracts are discarded in favour of cryptic bespoke Australian contracts designed to ensnarl other parties.

By contrast, when T. R Kuesel's paper "Contract Practices for Underground Construction" was published in 1974 there was a global sense of optimism and reform in all things including contracts. The USA had conducted



Professor Arnold Dix

a special report by the U.S National Committee on Tunneling Technology which had provided guidelines for improved contracting practices for underground construction incorporating a worldwide survey of current practice, including 'valuable impact' from Australian sources.

The passage of 50 years since Kuesel's paper highlights the poor contractual progress in the five decades that have passed. Particular issues discussed include:

Pre contract construction planning

The paper identifies one of the greatest sources of unnecessary cost in urban underground work to be the delay associated with third party agencies and recommends that the most effective means of countering this is for the Owner to become more involved in pre contact construction planning. This



Dr Charles MacDonald

proactive approach includes establishing rights of access to site, negotiation with regulatory agencies, advance relocation of utilities, advance demolition of structures and preliminary negotiation of construction permits, at least to the stage of establishing project wide agency agreements.

The authors believe this is an area in which good progress has been made in Australian practice, particularly in more recent years where Owner organisations have understood and accepted that projects can mobilise much more quickly and efficiently if the Owner has taken a proactive approach on these issues.

However, the corporatisation of previously state-owned enterprises such as utilities has created an opportunity for profiteering as those entities take advantage of the liquidated damages provisions for project delay.

Furthermore, agencies changing requirements part way through a project – with significant time/cost implications – is also grossly unfair and such matters should be within the responsibility and influence of the Government.

Site conditions

The paper reminds us that a distinguishing characteristic of underground construction is that the actual ground conditions are never fully understood until they are uncovered during construction. The paper then goes on to address a number of the consequences of this fact, and practices that should be adopted in the best interest of all parties. These include an encouragement to use 'latent condition' clauses that provide a mechanism for compensating the contractor in the event that actual ground conditions differ from those that were originally anticipated. The paper then criticises the use of 'elaborate exculpatory clauses' which Owners might adopt to absolve themselves of all responsibility for the accuracy of subsurface information furnished with the tender documents. The paper promotes a policy of maximum disclosure, without disclaimer clauses to elicit the minimum contingency in tenders.

Sadly, 50 years later such advice is still not adopted on many major tunnelling projects. Whilst the concept had not been developed at that time, Kuesel's paper outlines the fundamental principles behind the Geotechnical Baseline Report (GBR) which was developed in the USA in the late 1990's and thankfully is being increasingly adopted in contemporary Australian practice.

However, as graphically illustrated by recent experience in the Australian context, the consequences for governments not taking responsibility for regulatory changes that occur post close of contracts can result in burdens on contractors for unexpected and significant matters that were not

factored into a bid. The concept of a "regulatory base line report" has now been raised as a possibility for contract reform in Australia, but as of today there is little interest in it. The concept of paying a fair price for the project is still often absent from the contracting models in Australia.

Insurance

The paper promotes the adoption of what it terms Owner Furnished Coordinated Insurance or what we might now term 'project wide' insurance. The numerous advantages of such an arrangement including the need for all parties to work more collaboratively in addressing possible claims under the policy, are addressed at length.

Such insurance arrangements are now being increasingly considered, if not always adopted for major tunnelling projects. If the objective embraced by the Government was value based – "project wide" insurance would be the norm and it would be procured by the State.

Contract form

The paper provides a broad coverage of the various contract forms available at that time for the delivery of tunnelling works discussing the advantages and disadvantages of each. However, it does offer a strong criticism of the sole use of lump sum type contracts suggesting that they are not well suited to the uncertain site conditions inherent in tunnelling works. The paper suggests a combination of lump sum for predictable and more defined elements of the works, including matters dependent upon the contractor's selection of equipment and methods; and a 'schedule of rates' approach for less certain elements of the work including ground support measures and grouting quantities etc.

Again, in this section of the paper the principles that would later be enshrined in the Geotechnical Baseline Report (GBR) approach are carefully articulated. However, the paper also

makes the very important point, often not well understood by Owners or their contractual advisors, that the form in which the contract is drawn is far less important than the manner in which it is administered. Many costly disputes that have occurred in the last 50 years could have been easily avoided if this sage advice had been diligently adopted. Australia has an entrenched claims culture based upon aggressive litigation. However, more modern contracts such as FIDIC offer proven alternative mechanisms to run contracts with vastly lower levels of conflict.

General problems including escalation and prequalification

The paper also briefly covers a number of other topics suggesting that two of the most vexing issues in USA practice, at that time, were well addressed by the Australian General Conditions of Contract. These were the escalation of costs, a very topical issue in the early 1970's and becoming an increasingly relevant and critical subject in contemporary construction practice. The paper suggests that the 'rise and fall' mechanisms in Australian contracts had considerable merit. The second practice was the concept of prequalification which, whilst regular practice in Australia, was effectively prohibited by competition policies in the USA.

In summary, reading this paper illustrates to the authors how well the issues critical to the successful delivery of tunneling works were understood 50 years ago, and compared to the technical advances achieved by the industry in the last five decades, how little we have advanced in relation to Australian contracting practices. That said, the paper outlines the opportunities that were available then to improve practice and these remain available to Owners and contractors willing to adopt more collaborative and ultimately more cost-effective approaches to the delivery of major underground works.

Snowy Mountains Scheme | 1950



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50 years of shotcrete use in Australia

By E.S. Bernard, D. Vlietstra, and T. Bowling of the Australian Shotcrete Society



Dr Erik Stefan Bernard



Des Vlietstra



Tom Bowling

The history of shotcrete use in Australia is almost as old as the material itself. Early dry-mix machines were imported to Australia from the United States only a few years after their original development, and were used in Australia for water-retaining structures and ground support from 1914 onward. In the 1970s the material was used extensively for swimming pool

construction and in some tunnelling projects. By the 1980s fibres were starting to be used as reinforcement for tunnelling and mining applications. However, the most substantial expansion in shotcrete use took place in the period 1995-2005, during which ground support with shotcrete became standard for underground mines through Australia, and steel fibre

reinforced shotcrete became the most common means of ground support in civil tunnels. This paper will focus on the history of shotcrete use in Australia between 1972 and the present.

The term 'shotcrete' has generally been applied to concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface, but this process was originally commercialised under the patented brand 'gunitite'. Carl Akeley produced the first machine capable of projecting mortar with the assistance of compressed air in 1907 in Chicago (Bridger, 2017). His original machine was adapted by Allentown Equipment in 1909 to a process that is similar to some 'dry mix' machines that remain in use today. At least one of these machines was imported to Australia and used in 1914 to construct walls of



Modern shotcreting in progress

a water reservoir in Sydney, together with several other structures. The early 1930's saw the generic term "shotcrete" introduced by the American Railway Engineering Association to describe the guniting process, and since then the term 'guniting' (which essentially referred to sprayed mortar) has waned in popularity. In Australia the term Pneumatically Applied Mortar (PAM) was widely used to describe both guniting and shotcrete until the 1980s.

Shotcreting in Australia took a major leap forward when Ian Hay invented the swing-tube concrete pump in 1974 in the northern suburbs of Sydney (Hay, 2017). This type of concrete pump is now the dominant design used internationally. The majority of shotcrete produced in Australia at that time was used for swimming pools, but some dry-mix shotcrete (PAM) was used in various hydro-power projects and in transport tunnels.

Hydro-electric tunnels

The majority of tunnels in the Snowy Mountains Hydro-electric Scheme were constructed before 1972. However, regular maintenance and repair took place every ten years following construction and PAM (later shotcrete) was used extensively for this purpose. The majority of the length of Snowy Hydro tunnels were unlined, but unstable ground was initially lined with PAM reinforced with light mesh, and then with cast-in-place concrete. No quality control testing was conducted as part of the dry-mix spraying so the strength and durability characteristics of the PAM is unknown. The PAM contained aggregate up to 6-7 mm in diameter and can therefore be regarded as true dry-mix shotcrete. In subsequent inspections the steel reinforcement within the PAM was found to be severely corroded requiring the replacement of the PAM (Morrison, et al, 1988). This was often done using new PAM, but in more recent years wet-mix shotcrete has replaced the PAM as the preferred repair material. Fibres have also replaced the steel mesh. In general, the PAM and shotcrete was found to perform very well in the submerged pressure tunnels, but the steel reinforcement proved problematic.

Shotcrete was also used for slope stabilisation around the portals of some tunnels, and along roadsides and for drains. These applications were generally too minor to be recorded in any detail. However, in the more recent Snowy 2 Hydro development, shotcrete has been widely used for ground stabilisation in caverns, portals and slopes around many facilities.



Shotcrete has been used in Tasmanian Hydro Electric Commission (HEC) tunnelling work since the late 1950s. In general, it has been used to seal off shear zones or minor areas of broken ground where a full concrete lining has not been justified. The HEC started using steel fibre reinforced shotcrete on the King River Power Development in the late nineteen eighties. The King headrace tunnel runs from Lake Burbury on the eastern side of the Tasmanian West Coast Mountain Range to a power tunnel feeding the John Butters (surface) power station on the western side of the Range. The first 116m of the tunnel, which included the intake shaft, was fully concrete lined through poor ground. Downstream of this concrete lined section, for about 700m, shotcrete was used on about 38% of the area of the tunnel walls and crown. For the remaining approximately 5250m of tunnel to the start of the power tunnel, shotcrete was used to stabilise about 4% of the tunnel walls and crown.

Transport tunnels

Shotcrete use in civil transport tunnel construction advanced at a slower rate than was the case for hydro-electric projects, possibly because fewer

transport tunnels were built before the 1990s. The Melbourne Underground Rail Loop (Bishop, 1981) was an example of the relatively early application of shotcrete in transport tunnels in Australia. Dry-mix shotcrete was used for initial ground support throughout much of the excavation, mixed on site and sprayed manually. The Sandy Hollow Rail Line in NSW includes one of the first underground excavations in Australia known to be lined using steel fibre reinforced wet mix shotcrete, with construction completed in 1980. Starting in the late 1980s, road tunnel construction began to dominate civil tunnelling in Australia, with at first the Sydney Harbour Tunnel, then the Eastern Distributor, Norfolk Tunnels on the M2, and M5 East Motorway tunnel, all in Sydney, having been constructed during the 1990s. Each of these tunnels incorporated steel fibre reinforced wet-mix shotcrete for ground support, and were among the first projects to use alkali-free set accelerators.

These tunnels are unique internationally in that single-pass permanent fibre reinforced shotcrete linings have seldom been used outside of Australia. This form of lining has proven popular in Sydney because of

the highly effective bolt-based support possible in the local sandstone. The FRS lining primarily acts to protect the ground surface and provide local support, so quite slender linings that resist load principally in bending are structurally adequate. The Eastern Distributor tunnel was the first in Australia to include beam-based post-crack flexural toughness assessment of FRS in Quality Control (QC), and the original M5 East tunnel was also the first to use the ASTM C1550 round panel test for QC, a practice that has been adopted widely in ground support with shotcrete in Australian tunnels and underground mines.

Numerous FRS-lined road tunnels have subsequently been built throughout Australia and FRS is now a common part of underground civil infrastructure construction. Due to the adaptability of the shotcrete process, the most common application has tended to be projects involving non-regular geometry. Almost all shotcrete is applied remotely using FRS with alkali-free set accelerators together with hydration stabilisers and relatively large proportions of Supplementary Cementitious Materials.

Mining

Many Australian mines experimented with the shotcrete process in the 1980's but initial results were generally unsatisfactory largely due to spraying difficulties. Application was typically by hand-held dry-mix spraying and was unreinforced. Rebound rates as high as 50% made the process expensive, and dust was a major problem. Ventilation restrictions in underground mines meant that other work upstream of dry-mix spraying had to cease due to dust problems.

One of the first uses by an Australian mine of wet-mix steel fibre reinforced shotcrete took place in 1992, when Pasminco contracted Jetcrete to line their new pump chamber at Broken Hill using high quality steel fibre reinforced shotcrete. They also chose to line their raise bore sump with 50MPa shotcrete in preference to a steel liner on the basis of cost and superior speed of installation.

The introduction of wet-mix shotcrete virtually eliminated dust problems and sharply reduced rebound to below 20%. High volume applications became possible using robotic equipment, often with one-man crews. As productivity increased, prices dropped and the competitive advantage of shotcrete increased. Today, the most common method of shotcrete production in underground mining is to use a

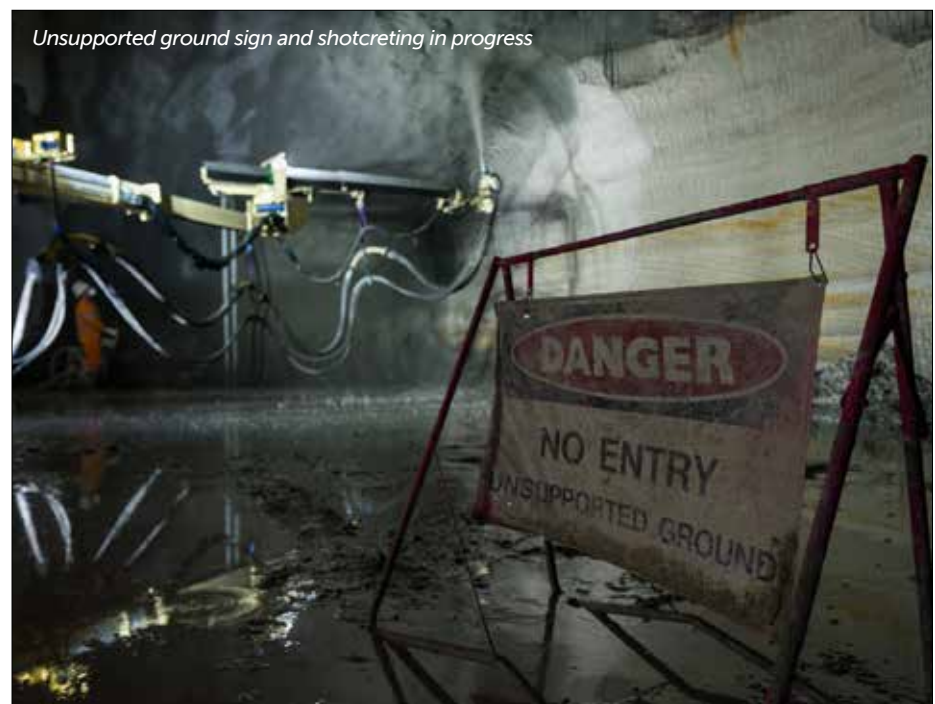
nearby commercial plant to produce the shotcrete mix. This is transported underground in standard five cubic metre agitator trucks and transferred directly to a robotically controlled shotcrete spraying machine. These arrangements generally allow for a good standard of mix production and a high volume of delivery.

From 1990 onward robotic equipment was generally adapted from existing underground plant. Eventually, as volumes increased, purpose-built equipment for robotic spraying was imported from Finland (Normet) and Switzerland (Meyco). A local brand (Jacon) also became available. In 1999, the MOSHAB ground support guideline was published in Western Australia. This stipulated that all excavations over 3.5m in height had to have surface rock support installed such as either meshing,

strapping or shotcrete. As a result, fibre reinforced shotcrete is today used widely throughout the underground metalliferous mining industry in Australia. Macro-synthetic fibres were introduced in the late 1990's, and from around 2012 onward FRS became increasingly used in underground coal mines (AuSS, 2020).

Summary

The application of shotcrete in Australia is now a mature industry with a multitude of uses limited only by one's imagination. It is an accepted means of ground support for excavations both below and above surface in civil and mining applications. Shotcrete is widely used for slope stability and lining of hydraulic structures ranging from the humble domestic swimming pools to large scale hydro-electric projects.



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50 years of tunnel systems in Australia

By John Rogers, Peter Howe and Robert Doubleday



John Rogers



Peter Howe



Robert Doubleday

Introduction

The delivery and operation of tunnels, particularly transport tunnels, involves close co-operation of many technical disciplines. While the ATS has historically focussed on ground and structural engineering-based disciplines, it has been recognised that successful tunnel projects require an understanding of the interaction between the various specialist disciplines.

The ATS has therefore sought to promote understanding and appreciation of Tunnel Systems through establishing a dedicated Tunnel Systems Sub Group and a Working Group to propose revisions to AS4825 (Tunnel Fire Safety), as well as organising technical presentations dedicated to the range of disciplines that make up Tunnel Systems, including

power, data, hydraulics and pneumatics.

As there were a number of road tunnels opened in Australia in the late 1960s and early 1970s, a brief comparison of those assets with recently completed road tunnels might best illustrate the advances that have been made in the past 50 years. Furthermore, we will focus on just two systems – one that the public sees (the tunnel lighting system), and one that is largely hidden to public view (the tunnel operational control systems).

Tunnel lighting

A fundamental safety requirement is for drivers to have adequate visibility when approaching the tunnel, at the moment of entry, within the tunnel and when exiting. To provide adequate

visibility, lighting systems are designed to overcome the “black hole” effect at the entry portal during day light hours.

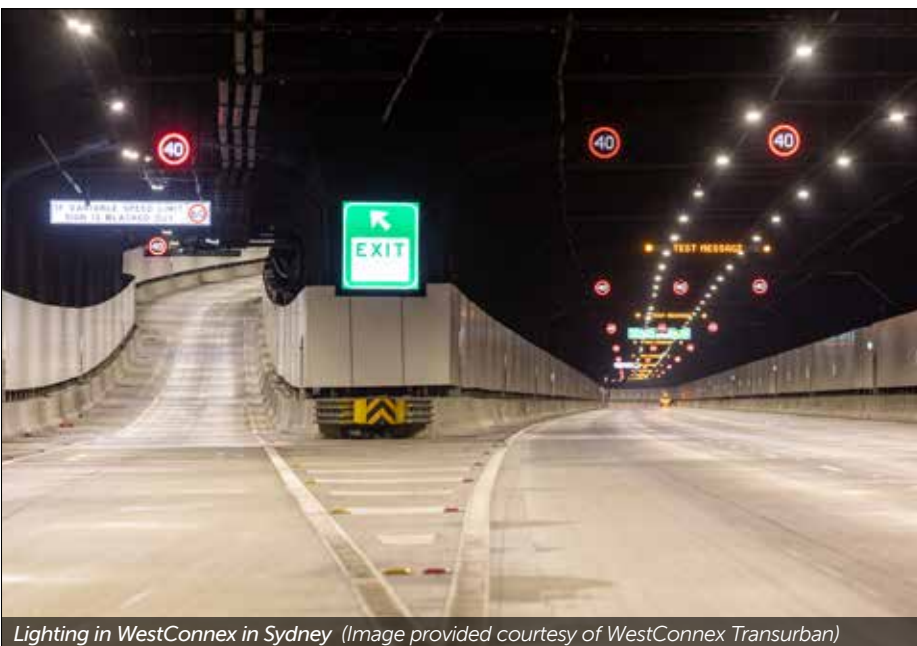
As the driver enters the tunnel their eyes gradually adapt to the lower lighting level which can be progressively reduced until a lower constant lighting level can be applied in a long tunnel. At the exit the eye adapts much faster to increasing daylight and boost lighting is provided for the driver to have adequate visibility in their rear-view mirrors.

The Sydney Harbour Tunnel (SHT) which was opened in 1992 was the first “very” long tunnel in Australia. This refers to a tunnel of sufficient length to permit a second interior zone where the lighting can be reduced to the equivalent of night time lighting. A luminance-based design, predicated on the portal surround luminance, quantified the levels of boost and basic lighting applied to both the road surface and tunnel walls. In another Australian first, photometric data for the high-pressure sodium (HPS) and fluorescent luminaires, together with reflectance data for all surfaces, were incorporated into a computer program to produce a compliant design that was later verified by measurement.

Evolution of tunnel lighting systems and solutions

Following the SHT example, tunnels in Perth, Brisbane and Sydney proceeded with a continuous end to end fluorescent lamp base lighting system supplemented by HPS boost lighting near portals. Continuous lighting is recognised as providing a more uniform and visually comfortable system without apparent dashboard flicker. However, the economics of spacing luminaires further apart could not be resisted. Fluorescent lighting systems with linear (long) light sources were permitted in guides and standards, as long as the dark space between the lighting tubes did not exceed the length of the light space. The Eastern Distributor tunnel in Sydney was the first of this generation.

Similarly, these standards allowed point source luminaires to be installed provided they met flicker frequency requirements. HPS lamps at up to 15



Lighting in WestConnex in Sydney (Image provided courtesy of WestConnex Transurban)

metres spacing were adopted for Mullum Mullum tunnel, Brisbane's Clem 7, Airport Link and Legacy Way. Since HPS lamps provided the bulk of exterior road lighting and tunnel entrance lighting, the deployment of HPS lamps, with their characteristic golden white colour, passed without apparent comment. Point source luminaires in road tunnel interiors are now the norm.

Throughout the 2000–2010-decade, LED light sources became a mature technology. Sydney M4 East (a very long) tunnel adopted LEDs for the interior lighting supplemented by HPS portal boost lighting. Sydney North Connex and M8 tunnel followed with a full boost and base LED lighting system. This solution was then repeated in the soon to be opened M4-M5 link tunnel.

Current and future challenges

There are a significant number of road tunnels in Australia approaching the end of their luminaire life span. This occurs when replacement spares for existing HPS/fluorescent systems become harder to source. Trials have been conducted with LEDs replicating linear fluorescent lamps without great success. Replacing HPS luminaires with higher powered LED luminaires resulted in early issues of temperature, however these have been gradually resolved.

A financial dilemma arises with the challenge of replacing HPS and fluorescent systems with new LEDs, or retrofitting new LED modules in existing housings. Night-time tunnel closures provide little time for existing maintenance so additional closures are necessary, but this means a loss of revenue in a tolled tunnel.

Ongoing compliance of the lighting with luminance and uniformity standards is dependent on both luminaire performance and the reflective elements of the tunnel, but measurements from some tunnels indicate that many older systems are struggling to achieve their design levels.

Maintaining the integrity of gasket seals becomes a problem with age. As the luminaire heats and cools with daily switching, a decayed luminaire seal allows grime to penetrate and hence internal luminaire pressure reduces during cooling. Control gear has a finite life, so lamp outages and internal grime accumulation are a constant maintenance issue. Availability of maintenance spares is an increasing concern and variations in fluorescent lamp colour are often an indication of this.

Luminance of the walls is a standards criteria for both quantity and uniformity. Reflective wall panels above the barrier,

in some cases, are coated fibre board or, more lately, vitreous enamel coated steel. It is remarkable how well the fibre board panels have retained their reflectivity through years of cleaning. On the other hand, concrete barriers with initial reflectivity of around 40% decline to as low as 15% as they absorb grime. Since luminance is a product of the amount of light falling on the wall or barrier and the reflectivity of the surface, the end result is a bright upper wall and a dark barrier resulting in loss of overall uniformity.

Many legacy lighting systems can be observed to be operating at an inappropriate level, either a "black hole" in the day time or over lit at night, indicating that maintaining the control system and photometers also presents problems.

Tunnel operational control systems.

The SHT Control System was the first use of an integrated traffic management and plant management sub-system with the one SCADA (supervisory control and data acquisition) control interface. This meant operators could manage both traffic and plant on the one screen, and interactions and dependencies between the two parts could be managed by the system without requiring the operator to manage two different systems. Also, back-in-the-day, redundant PLC systems had not been developed, and the designers used single-board computers on a redundant serial network connected to Opto-22 I/O to manage the physical device monitoring and control. Today, control systems use the most advanced technology, as can be seen in the table below.

A quick overview of some of the many technical differences between two milestone tunnel control systems 30 years apart

Technology	Sydney Harbour Tunnel 1991	WestConnex 2022 (3 Stages)
CPU	DEC Alpha	Dell Intel Xeon multicore
Operating System	OpenVMS	Microsoft Windows VMWare
Redundancy Technology	VAX Cluster	VSphere physical cluster + virtual machine backup
Plant Control System	Opto-22 I/O racks on Single Board Computers running MS-DOS	Rockwell ControlLogix PLCs with Redundancy Module
Ethernet Speed	10mbps	10gbps
SCADA Network	9600bps proprietary multi-drop serial protocol	Industry standard OPC and Ethernet protocols
I/O Count	30,000 points	150,000 points
Variable Message Signs	Proprietary serial protocol	RMS standard NTCIP compliant ethernet base protocol
Speed Limit Signs	VLSL with limited graphics displays	ISLUS (integrated Speed and Lane Usage) with graphics
Display Maps	Custom drawn adapted from civil cad drawings	CAD based, geo-located
CCTV Technology	Analogue	Digital
Traffic Incident Detection	Detector loop algorithms	Video processing



Original Control Room Sydney Harbour Tunnel



WestConnex Motorway Control Centre at St Peters (Image provided courtesy of WestConnex Transurban)

Lessons Learnt

Over the course of 30 years of development of over 20+ tunnels the key lessons learnt include:

- Common-mode failures for the unwary, e.g., a need to use redundant power supplies from different designs, highlighting the need for Reliability Availability Maintenance and Safety (RAMS) and Failure Modes Effect and Criticality Analysis (FMECA) (see below).
- The principle of isolated control network has evolved so that there is no connection to corporate/business network or internet.
- Intelligence has been pushed out to devices, e.g., IP-phones, smart cameras, digital radios, intelligent sign controllers, video incident detection.
- Transport for NSW's (TfNSW) Technical and Functional Requirements Specifications (SWTC) became established and well experienced. It is now a world leading known set of specifications.

Recent improvements

In the recent WestConnex Tunnels, TfNSW have mandated Human Factor considerations into the engineering design. This means looking into the man-machine interface to increase operator/user performance, efficiency and reduce risk of human errors. Factors such as information overload, too

many key-strokes, critical information presentation, operator comfort, complex procedures, and workflows are to be considered in the design.

Perhaps the biggest improvement over the past 30 years has been in the area of Systems Engineering Methodology used to ensure the production of quality and safe, software-based systems for critical life and safety assurance.

Thirty years ago, experience with Systems Engineering Methodology was in its infancy. Well understood procedures and processes were largely implemented from institutional and individual memory rather than being formally documented. Over successive years, TfNSW progressively included within their SWTC specifications additional design and process requirements to the drive industry to adopt International Quality and Functional Safety Standards, including ISO 9000 and AS61580. By following these well-established procedures and processes, we now produce demonstrably safe and reliable systems. Interestingly, safety, quality assurance and engineering process documentation now account for over 70% of the engineering effort, while actual software coding and testing account for the other 30%.

The Systems Engineering Methodology now encompasses:

- Requirements capture

- Initial design
- Detailed design
- Software production
- Module testing
- System testing
- Integration testing
- Requirements traceability back through design and original requirements
- Commissioning and site acceptance testing

This is also accompanied by the use of Safety Integrity Level (SIL) analysis to investigate and develop the appropriate level of safety and reliability, as well as formal numerical methods of RAMS, FMECA and Levels of Protection Analysis (LOPA), to identify and mitigate, where possible, potential points of system failure. All these processes and associated documentation are done to ensure and demonstrate the entire control system does what it is supposed to do reliably, safely and be maintainable.

This is not to say that systems produced 30 years ago were not safe and reliable. Indeed, the SHT has exceeded its availability target manyfold. However, today's systems are larger, interconnected and more complex than ever. The move to more rigorous system engineering processes has ensured that Australian tunnel systems will continue to be among the safest in the world.

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DELHI-GHAZIABAD-MEERUT RRTS PROJECT

TERRATEC has recently delivered three (3) new 7.51m diameter Earth Pressure Balance Tunnel Boring Machines (EPBMs) for India's first Regional Rapid Transit System Project to connect Delhi-Ghaziabad-Meerut.

TERRATEC's continuing success on global projects is a result of tailor-made robust TBM design, prompt onsite assistance, readily available stock of TBM spares and highly-skilled specialised TBM support throughout tunnelling operations.

50 years of rock cutting technology in Australia

By Alan Robertson



Alan Robertson

Rock cutting technology in Australia has advanced significantly in the 50 years that the Australian Tunnelling Society (ATS) has been the body representing Australian civil tunnellers and miners and all aspects of tunnelling.

The start of the era in the 1970's saw the introduction of roadheaders for mechanical excavation of soft rock (less than 50 MPa), but significant advances have been made since then, and particularly in the last decade, where hard abrasive rock in excess of 200 MPa is now being excavated by roadheaders. The performance and versatility of tunnel boring machines (TBMs) has also improved during this time and tunnel size increased.

Australia's first underground mining TBM project

The first Australian mine tunnels to be excavated using a full-face TBM (Ref 1, 1976) were started in July 1974 at Queenstown, Tasmania. The tunnels formed a major part of the underground expansion of the Mount Lyell Mining and Railway Co. Ltd.'s Prince Lyell and Cape Horn mines. A Robbins mole or TBM, four metres in diameter, was used by the R.U.C. Holland (Lyell) Joint Venture on a schedule of rates contract for the tunnelling of approximately 3,000 metres in two tunnels.

The machine had been used by Sydney Water and was modified for underground use with the segment installer removed. A wide range of rock conditions was encountered in these operations with average rates of advance in excess of 70 metres per week obtained for long periods, with a peak weekly rate of 105 metres. Transferring of the machine



Rock cutting technology

down and up the Prince Lyell No. 1 Shaft posed special problems. On completion of the project the machine was returned to Sydney Water for its final underground civil project. Subsequently, a TBM was utilised at Mount Isa Mines in the late 1970's in the 1100 Orebody to develop a conveyor tunnel for underground haulage. Comparisons between machine bored and conventional drill and blast methods of mine development at the time showed that the use of a mole was of value for longer tunnels.

Dosco Roadheader Mount Isa Mines

In the late 1970's a small Dosco Roadheader was trialed in the Mount Isa Cut and Fill (MICAF) lead orebodies (Ref

2, 2022). At the time I was the Mining Engineer for the Mount Isa Cut and Fill (MICAF production) after having worked for a short time as a hand-held miner in the upper MICAF orebodies using drill and blast mining methods. The trial using a coal cutting machine with cutting ability suitable for less than 100MPa rock strength was unsuccessful, with initial cutting of the blast fracture zone from previous drill and blast operations being relatively easy but once the fresh ore was encountered pick failures on the cutting head occurred. Had this trial been carried out with a modern high powered variable speed roadheader with cutting capability in excess of 200Mpa and variable speed drive, the results

FACTBOX

Australia excavates in excess of 30km per annum in underground civil tunnel projects and it is estimated by the author that tunnelling in Australian metalliferous mining excavation is in excess of 500km/annum.



Rock cutting in action

would have been significantly different. Smaller roadheaders, such as the Voest Alpine AM50 (now Sandvik) and Mitsui Mike, completed a number of small mine tunnel projects in the 1980's and 1990's and were well established in soft-medium strength rock tunnelling projects.

Mechanical rock cutting technology – an Australian initiative

Early Australian research into the concept of breaking rock in tension (the Unconfined Compressive Strength (UCS) for rock in tension can be one tenth of that in compression, thus requiring considerably less energy for rock fragmentation), rather than conventional cutting of rock in compression was carried out in the early 1990's at the University of Queensland by Dr Kit Bunker as part of his PHD on Oscillating Disc Cutter (ODC) technology.

Through the Cooperative Research Centre Mining at the University of Queensland the concept was further developed with cutting trial research by an Australian Company, Terratec Australia, so that by 2013 trial machines were developed with equipment manufacturing companies including Joy Global and then Sandvik, marketed as DynaCut Technology. Sandvik uses the ICUTROC technology utilising discs that undercut the rock. Epiroc has developed the highly automated Mobile Miner

continuous mining system utilising disc cutters to excavate hard rock, specifically for mine development.

Largest diameter TBM project in Australia.

The largest TBM in the Southern Hemisphere, Bella Guerin or Bella for short, is being used currently in the West Gate Tunnel (Ref 3, 2022). The massive 15.6 m diameter TBM was sent on its journey under Melbourne's western suburbs to build the alternative to the West Gate Bridge. It is currently working its way through the earth below Yarraville and will travel for 18 months, finishing in August 2023, excavating the 4km outbound tunnel that will meet up with the West Gate Freeway in Altona North. The second TBM, named Vida Goldstein, has begun work on the 2.8km inbound tunnel.

New technologies: mechanised cutting rectangular section

A rectangular profile hard rock cutting up to 200MPa developed by Robbins (Ref 4, 2021), the Mine Development Machine (MDM) 5000, used in the Fresnillo silver mine in Fresnillo, Mexico is yet to be used underground in Australia. The MDM 5000, based on mining industry requirements for a light, highly mobile productive machine, cuts a 5m wide by 4.5m high rectangular cross section with advance rates up to 52 metres per week in 100-150 MPa rock. A major advantage

over circular TBM profile cutting is that where a final flat floor is required for road and railway tunnels, 30% less rock has to be excavated and there is no requirement for invert back filling. Hence the MDM 5000 offers major advantages for most large civil and mining tunnelling projects.

The next 50 Years of rock cutting in Australia

The next 50 years will see the introduction of competitive rock cutting technologies in underground mining and civil tunnelling in Australia. They will be associated with improved rock cutting performance in harder, more abrasive rock and the introduction of sophisticated technology including autonomous operation. High performance flexible roadheaders will be effective in creating underground space in our cities with low impact on the environment and community.

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50 years of grouting in tunnelling in Australia

By Bruce Grant and David Lees



Bruce Grant



David Lees

Following the Underground Space Project carried out by the Warren Centre in 1996, Australia had a resurgence of underground tunnelling works, starting in Sydney and then spreading out across the country. This required, in many instances, a fresh look at grouting to control water ingress in underground works.

Looking back to the start of the Australian Tunnelling Society's 50-year history takes us into the early 70's, coinciding with the formation of the Melbourne Underground Rail Loop Authority in 1971 and the start of construction on the Melbourne City Loop. Although this project and the following two decades of tunnelling projects saw a great deal of development in tunnel design and construction, the use of grouting as a means of groundwater control was not high in the hierarchy of control measures and not commonly practised. Groundwater was typically managed via traditional methods of dewatering, drainage, pumping and waterproofing within the lining systems as necessary. Some of these structures have needed extensive repairs of the concrete lining in recent years to combat water ingress.

In this period of the 70's and 80's, grouting practice had been well developed, through foundation engineering for dam construction. A.C. Houlsby, who was an engineer for the Water Resources Commission of NSW, produced perhaps the first "how to" grouting manual called Construction and Design of Cement Grouting. Published in 1990, it was a comprehensive guide to grouting in rock foundations. Many of the

subsequent specifications that included rock grouting for tunnelling works were derived from this work by Houlsby.

Although it continues to be a valuable resource for surface-based grouting works, this reference did not directly apply to grouting underground at the tunnel face. Materials technology was needed beyond the traditional use of Ordinary Portland cement, bentonite and bulk fillers to create more modern materials to meet the increasing demands for water tightness.

In 2001, the Norwegian Tunnelling Society issued its first major publication on the subject titled Water Control in Norwegian Tunnelling. This was followed in 2011 by Rock Mass Grouting. Here the world of tunnelling was introduced to Scandinavian practices for the first time and the introduction of microfine and ultra-fine cements became more widely practiced, as did the application of higher grouting pressures, use of multi-boom computerised drill jumbos, computerised multi-pump grout platforms and the primary application of pre-excitation grouting in general.

The influence of Scandinavian grouting knowledge and experiences into Australian underground

construction was further developed by international practicing engineers such as Orjon Sjoström. Although based in Hong Kong, Orjon provided inputs for Sydney's Northside Storage Tunnel and Melbourne's Eastern Freeway tunnel (EastLink) projects in 1999 and 2004 respectively. Knut Garshol was also influential with his work for MBT- International's Underground Construction Group and his 2003 publication Pre-Excavation Grouting in Rock Tunnelling. In the late 1990's, Skanska subsidiary Stabilator made some inroads to the underground sector in Australia, bringing with it some highly valuable grouting expertise and links back to knowledge bases in Hong Kong and Scandinavia.

The first project to introduce microfine cements in the country was the Sydney LPG Cavern excavation in the late 1990's at Port Botany. Here the French consultants Geostock, mistook the low Lugeon value for fine fractures and specified the use of microfine cements with superplasticisers. However, the bedding planes in the Hawkesbury Sandstone in this area were largely filled with clay and it was this that gave the low Lugeon values. As such the grouting succeeded in



Adelaide desal grouting subsea riser connection

creating grout lenses within the clay filled bedding planes (Lees and Edwards, 2005).

Excavation of the Northside Storage Tunnel below Middle Harbour in Sydney in 1999 required a strategy of forward probing and grouting from the TBM. Forward probing and grouting was carried out over a tunnel length of about 210m which equated to the area beneath a palaeochannel assessed to have been influenced by valley bulging. Up to 54 grout holes were drilled prior to each 4m to 6m advance of the TBM. Groundwater inflow in the tunnel after the grouting was estimated to have been reduced from a potential 200L/s based on back calculated permeabilities to 18.5L/s for this section of tunnel, i.e., a grouting "efficiency" of some 90% indicating a permeability of the grouted ground of 0.7×10^{-7} m/s (Kim et al, 2021).

In 1998, the Eastern Distributor Tunnel passed through some of the dykes in central Sydney, this was followed by EnergyAustralia's CBD and City East Cable Tunnels in 2003. These features were typically hard dolerite bounded by fractured sandstone and transmissive conditions were anticipated in the immediate area of the dyke so pre-grouting was performed in this zone. Here microfine and GP cement grouts were used and some limited post grouting was required to reduce flow by approximately 80-90% (Lees et al, 2005). Problems, particularly in the TransGrid Tunnel with latent ingress bringing iron rich sediments into the tunnel, promoted extensive use of chemical grouting to reduce the final impact.

Hewitt (2005) reports that for the Epping to Chatswood Railway the maximum inflow criteria was stipulated as 0.1 L/s/100m or 1 L/s/km, but initial inflows of up to 3 L/s were recorded which were treated by in-tunnel pre-excavation grouting and post grouting and resulted in 0.12 L/s/km.

In 2003, a significant challenge identified in the construction of the Parramatta Rail Link was the cut and cover crossing of the Lane Cove River. Geotechnical and hydrogeological studies identified a significant joint swarm and horizontal transmissive feature at about 5m to 15m below top of rock, typical of valley bulging effects in the Sydney Basin. Water pressure tests from surface identified extremely high permeability results up to 100 Lugeon and curtain grouting was carried out to limit water inflows which was very effective in reducing the rock permeability to between 1 and 5 Lugeon, sufficient to address the inflow criteria (Lees et al, 2005).



Grouted rock mass in a copper mine

For the Lane Cove Tunnel in Sydney in 2005, grouting was limited to tunnelling under the brick pit at the Pacific Highway portal and beneath Stringybark Creek. Although the actual water inflows from the drill holes of the grouting fans were relatively low beneath the brick pit, grout-takes in many cases were high, indicating the potential for high inflows (Lees et al, 2005). Hewitt (2005) reports that there was only 9m cover to the tunnel at Stringybark Creek and that the creek bed exhibited open joints in the sandstone which were considered to extend to the proposed tunnel below.

In 2016, WestConnex 2A stipulated the 1 L/s/km rule and according to Raymer et al (2019), significant pre-grouting from surface was carried out in the Arncliffe area where the site investigation showed the average hydraulic conductivity typically exceeded 10-5 m/s (100 Lugeons). This was followed up by pre-excavation grouting underground using ultra-fine cements. In the Arncliffe area, there were numerous large, open, horizontal fractures at tunnel depth, some with apertures greater than 100mm. These large fractures were thought to be from valley floor bulging beneath a deep paleochannel combined with shearing associated with the Woolloomooloo Fault Zone. The purpose of the pre-grouting from surface program was to fill large fractures with Ordinary Portland cement in order to build a foundation for additional pre-excavation grouting from underground, which was to fill finer fractures and bleed channels with ultrafine cement.

For the WestConnex 3A M4-M5 Link in 2018, the tunnels crossed the

Haberfield Dyke and the Hawthorne Canal, which were identified as areas of potentially large inflows due to an average permeability of about 10-5 m/s in some places. Pre-grouting from underground was carried out through the Haberfield Dyke; the grout takes were very high and the resulting water inflows were low. Pre-grouting from the surface was carried out near the Hawthorne Canal (Kim et al. 2021) with extensive pre-grouting performed underground through the broader Hawthorne Canal zone.

The designers for the Melbourne City Link in 1996, prescribed pre-excavation grouting but this was not successfully carried out and, unfortunately, the hydraulic connection between the rock being excavated and the sensitive surface deposits started to create settlements of some important structures such as the Melbourne Tennis Centre. It now being too late to achieve the desired drained tunnel, the tunnel was redesigned as tanked. However, there was still significant water ingress into the tunnel and remedial grouting was undertaken. The difficulty now was to determine where the water was coming in to the tunnel as it could travel along the concrete lining some distance from its source. This was achieved by breaking the tunnel into sections by grout fans around the tunnel (Lees and Grant, 2004).

Currently under construction in Melbourne, the Northern Portal of the West Gate tunnel is constructed adjacent to Whitehall Street and is the launching area for the TBMs being used to excavate the twin tunnels. The temporary anchored piled wall from



Sydney Metro cross passage grouting

tender was replaced with a soil nail wall for soil/fill and spot bolts rather than pattern rock bolts supporting basalt at depth. A temporary reinjection scheme for contamination plumes was introduced, with grouting around the excavation to limit inflows/drawdown prior to the permanent tanked structure (Lees, 2019).

Whether it is Sydney, Brisbane, Melbourne, or Perth metro rail TBM projects, grouting the ground prior to cross passage excavation is commonplace. This includes sub-sea situations, for example under Sydney Harbour or Adelaide Desalination project where grouting for the sub-sea intake and outflow risers was an essential element of the works.

Road, rail, water, sewerage, electrical utilities, hydro power; on most, if not all tunnelling projects in Australia, grouting of varying forms is practiced, playing an important role in controlling groundwater ingress and contributing to the ever-increasing demand for drier, "watertight," 100-year design life tunnels, particularly in our complex urban environments.

Modern materials, manufactured locally or imported, play an important part, whether this is special fine ground injection grouting cements, numerous additives to enhance or vary the grout properties, or specialty chemical grouts tailored to solve problems in many different situations. However, the application of these modern materials requires a refined knowledge and experience to perform this work efficiently and effectively.

The development in grouting materials technology and practice in the last 30 of

50 years has seen parallel development in equipment technologies, particularly in computerisation. Multi-boom drill jumbos for long hole drilling are highly mechanised, fully computerised and efficient, eliminating manual handling, and with the implementation of Measurement While Drilling (MWD) technology can provide details of expected geological conditions ahead of the face. Grouting plants, although still using long established, efficient colloidal type mixers and pumping units, are available as fully computerised units along with the control system and data logging capabilities that support efficient operations and critical data

analysis.

In Australia, such high-tech equipment is in use for surface based grouting activity but still a rarity in the more confined spaces for underground grouting. However, with the demands for tighter groundwater control in urban tunnelling, the values of these technologies is increasingly recognised.

As we continue with underground construction in more challenging situations, the demand for experienced people in this specialised field is needed more than ever and the reinvestment in modern drilling and grouting equipment vitally important.

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50 years of tunnel geotech in Australia

By Helen Baxter-Crawford, Principal Engineering Geologist at SMEC

My Grandfather was a chief engineer for the Snowy Hydro Scheme (which was constructed between 1949 to 1974). My Grandmother was a coal miner's daughter. So, I guess you can say that digging rocks is in my blood. Despite this pedigree, my first memory of tunnels was as a poor university student doing everything possible to avoid paying the new Eastern Distributor's toll. While those memories and my subsequent experience mapping, modelling and designing tunnels may be limited to a bit under a quarter of a century, the tunnelling community has been pushing the envelope in Australia for much longer.

The first tunnelling that required rock mechanics input in Australia was Busby's Bore, a water supply tunnel in Sydney built 1827-1837. However, due to a focus by the Australian sector on soil geomechanics in the early 20th century, development of permanent rock tunnel support began a lot later. Kömürlü and Kesimal (2016) provide an enlightening history of rock bolts in tunnelling throughout the world. Within Australia, the use of rock bolts dates back longer than the Australian Tunnelling Society to my grandfather's project, Snowy 1. This pioneering project which began in 1947, not only saw the first Australian use of mechanically anchored rock bolts for large diameter tunnels in highly fractured rock, but brought forth a name resonant with the industry – David Coffey.

Despite Snowy 1 bringing geotechnical engineering and engineering geology, as we now know it, to Australia, the path from Snowy 1 to this century was mostly driven by our mining associates. The stresses contained in the rocks and excavated spaces of deep underground mines required thought development. Hence the arrival of cable bolts in the 1970's. Next came energy absorbing rock bolts (for example the Garford Bolt) to counteract the risk of rock bursts. The civil industry brought us the other extreme: shallow cover caverns with flat roofs like the Sydney Opera House carpark that used combinations of tensioned bar anchors and un-tensioned galvanized dowels to create internal



Bolting installation using jumbos, with the rock bolts mechanically lifted into position.

reinforcement (Pells, 2020) with strict controls that there is to be zero surface damage during construction. Modern day civil tunnels have shifted the focus to sustainability, cost savings and making the ground support itself. Rock bolts are now being designed to support the weight of tons of rock AND have a 100-year design life, double corrosion protection, fire resistance, be testable in-situ and have the ability to withstand the impacts of seismic activity.

Tunnelling is more than just what type of rock bolt is most effective. Safety has played a huge role in how bolting is physically achieved. I still remember my first underground experiences in the Epping to Chatswood Rail-line (ECRL), seeing the shift boss of the roadheader physically hoist the 6m long cable bolt into the bolt hole by hand, balanced on the head of the roadheader. He resembled a pole vaulter in hi-viz. Not long after, bolting installation using jumbos with the rock bolts mechanically lifted into position became the norm.

Not only were these safer, but some models had the capability of installing 30–45 bolts, on average, per hour. For most Australian capital cities, where the local geology ranges from medium to high strength rock which is suited to road-header excavation, this outcome promoted the use of multiple road-headers in a split heading configuration. A tunnel face could be excavated by two machines simultaneously, with one working slightly behind the other, both cutting

rock within the swing-reach of the cutter-head. This meant the only plant movement was tunnel parallel, smaller road-headers were viable, spoil could be dumped directly into trucks rather than conveyers and resulted in faster cuts and double the excavation progress.

It was the 1950s when engineering geology became a focus for rock mechanics with the likes of Danny Moye and his "trainee" Barry McMahon devising principles and techniques for data collection still used today (Poulos, 2020) as critical inputs to tunnelling, again on Snowy 1. The observational method was used during construction where simple weathering-based rock mass classification schemes were correlated with support types and construction observations used to refine the classification and support according to actual conditions, ultimately producing significant savings. It was this project that saw the importance of defect orientation and condition





as inputs to design. The subsequent concepts of Q, Rock Mass Rating (RMR) and Geological Strength Index (GSI) have become fundamental tools for the geologist to convey the rock mass conditions to engineers in a way that engineers understand – using numbers in order to install the appropriate designed support. The use of rock mass classing systems and assigning support criteria to each class has positively impacted the pre-construction budgeting to actual costs ratio, improved advance rates and improved construction sequencing. The use of routine monitoring, mapping and checks during excavation (observational method of risk management), gives geologists further understanding of the inherent uncertainties of the ground and its behaviour.

The permit to tunnel procedure, developed in Australian tunnelling projects over the last two decades, allows the geological team daily input into whether the tunnel design should be adopted for upcoming excavation or if conditions are deviating from those anticipated and modification is required. This has, however, created unprecedented demand for geological staff, which the entire sector is struggling with. The lack of recognition by Engineers Australia to the Engineering Geologist or Tunnelling Engineer as a discipline and area of competence is an increasing challenge for universities and industry alike. Back in my ECRL days, I would map the days' excavation in quiet and relative safety during the non-operational maintenance period. Alone, looking after one site. Today, we have 24/7 excavation on multiple fronts, requiring 24/7 coverage by geologists who now also have to do the job in a fraction of the time due to mandatory shotcrete support. Addressing this staffing shortage will dominate our

ability to continue such large-scale civil projects going forward.

Where can we go from here? Can tunnel design and construction be further improved? Absolutely. From a geological modelling perspective, I see two key areas that can be improved, one for all tunnelling projects and one which may be considered Sydney specific, but for which consideration would value-add to any project:

1. Standardising structural data measurements, and;
2. Inflow criteria for Sydney's rocks.

The televiwer is a probe used to image the side walls of boreholes, allowing collection of orientation data and defect condition to be collected in-situ. It is now widely used for tunnel project geotechnical site investigations. The images are interpreted, with the outputs then used as inputs to large scale structure model development, assessment of block volume size and potential for wedge formation, etc. However, there is no standard for achieving this interpretation. While core logging is standardised using AS1726 (2017), such that all defects are described using a set of codes, the televiwer data being provided for projects often doesn't reflect this. As the televiwer data is effectively a reverse image of the core, should we not use the same descriptive codes to describe it? How can we compare our two data sources if we do not?

In essence, a joint logged in the core should be logged as a joint in the televiwer unless the in-situ conditions suggest it may be something other than a joint. The televiwer then provides us with the additional data of the orientation and aperture, amongst other things. Adopting a coding convention

commensurate with AS1726 (2017) would significantly improve our understanding of the rock mass.

Groundwater is another challenge, particularly how to manage groundwater drawdown combined with the contractual requirement of 1L/second/km (in the case of Sydney's Hawkesbury Sandstone) for long term groundwater inflows. The basis of the inflow criteria for Sydney rocks was measured inflows from drained cable tunnels developed pre-early 1990s which, for those specific tunnels, the data supported 1L/second/km as a value that could reasonably be expected without having to resort to grouting – the 50 years of grouting paper within this volume is a testimony to this not being the case. The originator of the criterion also states it was never supposed to be carved into the Rosetta stone (Philip Pells, personal communication). We have the data to recalculate typical background groundwater flows and improve costs and the potential for latent conditions claims on projects. Why is it not being used?

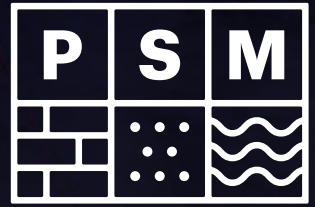
I would like to thank the ATS for asking me to write this piece and congratulate the society on this important milestone. It is very humbling to be part of this fantastic community.

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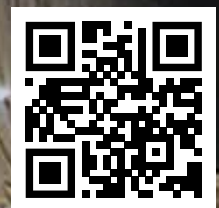
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30
YEARS OF

TUNNELLING

FIRSTS



EASTERN DISTRIBUTOR

- Largest Span
- Hawkesbury Sandstone
- Double Decker

1997

2001

BURNLEY TUNNEL

- Tunnel Remediation

LANE COVE TUNNEL

- Handlebar Plate

2002

2009

BRISBANE AIRPORT LINK

- Largest Span
- Brisbane Tuff

M2 WIDENING

- Widening of Operational Tunnel

2012

2013

NWRL

- Largest Span
- Ashfield Shale

WYNARD WALK

- Primary as Permanent Support

2015

2017

M4 EAST

- Largest Span
- Hawkesbury Sandstone

CROSS RIVER RAIL

- Largest Span
- Neranleigh Fernvale

2020

2022

ROZELLE INTERCHANGE

- Multi-level Tunnelling

Tunnel support design – how lessons from the past are informing the future

By Robert Bertuzzi and Andrew de Ambrosis, both are Principals at PSM

Introduction

This article looks at how tunnel support designs have been implemented in the past, what changes have occurred and what lessons can be learned. A wonderful timeline of projects is presented in this journal. Alas, the authors can't speak to all these impressive projects but attempt to collate their experiences since the early 1990s, when PSM started.

At that time there was a steady stream of tunnelling work predominantly in Melbourne and Sydney. Tunnel designs typically included support types that were to be installed dependent upon the encountered conditions. The designs were fully developed and reviewed. There was no primary intention to vary the design during construction. The ground movement was monitored primarily to check performance. Design changes were not intended to be based on ground response.

The conditions that controlled support were documented in the design and were predominantly, but not exclusively geotechnical. Some conditions were simple, e.g., comparison of rock strength

to that of concrete (Melbourne's Burnley Tunnel); some conditions required more specialised skills, e.g., Sydney Classification System (Sydney's Eastern Distributor) and the Q-system (Sydney's M5 East).

The encountered conditions were decided by the engineering geologist, who was employed by the tunnelling contractor, and who then informed the tunnel engineer, who also was employed by the tunnelling contractor. The tunnel engineer would then choose, perhaps in consultation with the engineering geologist and / or shift boss / superintendent, which of the designed support was to be installed.

Observation

Were the 1990-2000 designs an "Observational Method"? Is a design that provides different support depending on conditions, an "Observational Method" or is it just providing options?

If the rock that will form the pillar is of good quality, then the pillar can be formed within that rock. If the rock is of fair quality, then the pillar can be formed within that rock, but with additional

support, say bolting. If the rock is of poor quality, then the rock will be excavated and replaced with concrete. These three rock-condition-dependent options are provided in the pillar design so that what is implemented in the field is dictated by the conditions of the encountered rock.

For all three options, the response of the pillar may be monitored. Adverse movements may trigger a design review. That is, the observed conditions of the rock determine the type of pillar formed.

Or at least, it could be. The Contractor could take the view that it is better for its programme to commit to replacing the pillar with a concrete block right from the onset and disregard the rock quality.

To the authors, the term "Observational Method" implies more than what has been practiced. More than just a design giving options and checking a response. If it doesn't then what's the point of the word "Method"? The single word "Observe" would suffice for our tunnelling design in general.

It really doesn't matter what label is given, though there is a caveat as parties have claimed "Observational Method"

29m wide span in the M4East tunnel in Sydney, 2019



on projects to gain a contractual advantage.

Permit to Tunnel

The implementation of the design described above remained the process until the Permit to Tunnel (PTT) was introduced for Brisbane's Airport Link Project in 2009. The PTT provided the framework for people in charge of the tunnelling to formally discuss and confirm that there is a design available that suits the encountered conditions and where a design is not available to raise a request for information (RFI) from the Designer. It forced a pause for the people in charge to consider the encountered ground and its response to the tunnel excavation. The PTT has proved to be a successful innovation to our industry.

Recently, there has been a push to have the Designer attend the PTT meetings. Prima facie it appears to be a good step to include the Designer at this meeting to discuss whether the available design is suited to the encountered conditions. Yet, it is the authors' contention that having the Designer attend the PTT meeting is not in the best interest of the Project.

It does not assist the Owner, the Contractor, nor the Designer, to have in the PTT meeting the people that may want to change the design, the Contractor, say to suit its construction programme, and the people that can change the design, the Designer. It opens the situation for the ad hoc design changes discussed by Clark (2021) and Bertuzzi et al (2022).

Further, there is no one Designer. Invariably the design involves numerous people, so it is unlikely that one person is completely across all the elements that contributed to the solution. Consider the interaction between the geotechnical model, tunnel designer, M&E, durability, predicted effects, constructability – the whole purpose of the internal reviews - the pink version, the war room, and now commonly referred to as the Cross Discipline Review (CDR).

Design Review

It is reasonable to expect that as we develop more tunnels, it would be cheaper to design tunnels. Yet, in practice our industry has seen design costs increase.

Bertuzzi & Rouvray (2014) estimated the cost of the review process to a project back then, to be approximately 1.5 times the design cost. That cost has now been surpassed. It is estimated that the review of a design will cost a project built today more than double

the cost of its design. Further, and more concerning, is that the Project's focus is now the review. How to get through the review process as expediently as possible for the construction programme, which is essentially dictated by the client's agenda, rules. It is a sad reflection upon our industry that this has happened. As an industry we should ask, are we receiving value for money?

Conclusion

This article briefly presents some of the views of its authors, formed by their collective long-term experience

in our industry but, nevertheless, they are personal opinions. The opinions of others, who have also been exposed to similar experiences, will no doubt differ. That is benefit of belonging to a technical society; the bringing together and sharing diverse views.

Acknowledgement

The authors have benefitted from sound engineering apprenticeships with some of the young 1970s and 1980s start-ups and hope to have, and to continue to, share this tradition with the next generations.

Biographies



Robert Bertuzzi - Robert graduated from the University of Sydney in 1985 as a mining engineer and started his career in a Hunter Valley underground coal mine. His first tunnelling job was on the UK Channel Tunnel along with many of Australia's tunnellers of that generation. Since joining PSM in January 1994 Robert has continued tunnelling. Personally notable among them is the Sydney's Eastern Distributor (double decker, 24.5 m span which was big then, setting the 'standard' Sydney tunnel support), Sydney Metro Northwest (23 m span crossover cavern in Ashfield Shale), and Brisbane Cross River Rail (complex geology, multiple large station caverns). In 2017, Robert was awarded a PhD from the UNSW Sydney for his thesis, "Rock mass properties for tunnelling."



Andrew de Ambrosis - Like many in our fraternity, tunnelling is somewhat of a family affair for Andrew. His first proper underground trip was in the mid-90s as an engineering student, accompanying his father during the construction of the Elgas caverns at Botany in Sydney. After finishing his PhD at the University of Sydney, Andrew's first real tunnelling design job was the Epping to Chatswood Rail Link (2001). Back then it was known as the Parramatta Rail Link, but it never quite made it to Parramatta and hence the name change. Since then, Andrew has been fortunate to be involved in many of Australia's amazing array of underground infrastructure projects. Some notable examples are Brisbane's Airport Link (Kedron Caverns), Sydney's Wynyard Walk (a small, but highly constrained CBD pedestrian tunnel), WestConnex M4East Caverns (which at 29m were the widest spans constructed in the Hawkesbury Sandstone) and more recently WestConnex Rozelle Interchange Project (which surely holds the title for Australia's first underground spaghetti junction).

Robert and Andrew continue teaching for the UNSW Master of Engineering Science course.

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Waves of tunnelling

Dr Philip Pells has been a member of the ATS since the start and has attended all 17 Australian Tunnelling Conferences since the very first one was convened in 1974. He has expertise of global renown in the areas of geotechnical engineering and rock and soil mechanics and, although now officially retired, Philip continues to provide intermittent consulting via his son Steven who runs the family business, Pells Consulting. In this personal view, Philip neatly summarises the projects that have propelled the Australian tunnelling industry forwards over the last 60 years:

“In my mind, civil engineering tunnelling in Australia has moved, and developed, in waves. Each wave has included innovations and innovative thinkers whose ideas and actions then merge into the psyches of designers and contractors.

The first wave occurred when I was an undergraduate student in South Africa. This wave was the Snowy Mountains Hydro Scheme and peaked in the early 1960’s. Even though I was living far away, I was aware of the innovative use of rock bolts to reinforce rock (to support itself), and the world-leading development of engineering geology by Danny Moye.

I was also overseas, in England, for tunnelling’s second wave. This was epitomised by the Poatina Cavern

project in Tasmania in around 1963 with the clever approach to dealing with bedded sandstone where the virgin horizontal stresses are substantially greater than overburden pressure. Lance Endersbee’s paper on Poatina remains one of the classics of rock mechanics. The momentum of the first two waves led directly to the establishment of the technical society now known as the ATS.

I had arrived in Australia in time for the third wave, the epicentre of which was Melbourne in the period 1972 to 1980. This was not just driven by the Melbourne Underground Rail Loop Authority, but the Melbourne Metropolitan Board of Works. Tunnel designs were innovative and the development of tunnel boring machines

(TBM), nurtured by David Sugden, were on the global cutting edge.

The rest of Australia offered little to tunnellers at that time, and I still remember a talk given by Bill Bamford, who noted the best Sydney could offer were the cut-and-cover tunnels at Kings Cross and The Domain. (This was probably a little unfair because the TBM tunnels and associated stations for the Eastern Suburbs Railway were not trivial.)

Then came the fourth wave in Sydney, starting in the early 1990’s, in which I, fortunately, was involved. It started with the three Ocean Outfall Tunnels, but it was the Bondi Pumping Station Cavern which allowed us to bring together the rock reinforcement expertise of the Snowy, the skilful ideas from Poatina and Evans’ (1941) paper on the concept of linear arches.

This fourth wave kept breaking for a long time and included the Sydney Harbour Tunnel, the Opera House carpark, the Eastern Distributor and the Cross City and Lane Cove tunnels. Adelaide did butt in with the Crafers Tunnel in 1996– but this was more-or-less an extension of Melbourne-inspired experience and skills.

But Brisbane was not to be outshone. Inspired by the then Lord Mayor, Jim Sorley, Brisbane ushered in the fifth wave in 2002 with the North South Bypass Tunnel (M7 Clem Jones Tunnel), followed by Legacy Way, Cross River, and the Airport Link.

Now we are in the middle of the sixth wave, happening everywhere but particularly in Sydney with NorthConnex, WestConnex, M5 East duplication, NW rail link, and a soon-to-be second harbour tunnel. Melbourne and Brisbane are building rail tunnels and underground stations, and Perth is not to be forgotten as they contend with sands and water.

Along the way there have been some wipe-outs and, unfortunately, human tragedies but, overall, the last 50-plus years of tunnelling in Australia has been one hell of a surf.”

“Along the way there have been some wipe-outs and, unfortunately, human tragedies but, overall, the last 50-plus years of tunnelling in Australia has been one hell of a surf.”



Enjoying a dinner date on the lowest level of the Opera House Carpark, on the first spiral of the double helix

Stories and messages from members

The quiet heroes

By Ed Ang

I'd like to dedicate this 50th anniversary of the ATS to all the unsung heroes; the quiet women and men in the tunnelling industry who've invested their time and effort to nurture the next generation of engineers and technical professionals. Specifically, I'd like to acknowledge my mentor, Ray Christie. I owe much of my rail knowledge to Ray.

Sydney Metro Northwest was the first fully automated train service in Australia and, for Ray Christie, the last major project prior to his retirement after over 40 years quietly improving the rail network in NSW. Now, reflecting on the three years since the opening of Sydney Metro and my professional achievements, the knowledge I have, can, in large part, be traced back to the time I spent with Ray. He was always patient with my many questions and I vividly recall our night visit walking through the entire Epping to Chatswood Rail Link tunnel exploring some of the features.

Throughout my career, I have been exceedingly lucky and blessed to have gracious and experienced mentors like Ray who took the time to nurture an aspiring engineer. As an industry, we benefit immensely from experienced professionals like Ray and it is imperative for us to take time to recognise the quiet achievements of all the unsung heroes.



"If I have seen further, it is by standing on the shoulders of giants."

Sir Isaac Newton

Ed Ang is an Associate Director - Strategic Engineering of AECOM. He has been a member of the ATS for three years and joined to better connect to the tunnelling community. He is currently part of the new Tunnel Systems Sub Group.



"Helping to put together this special issue of the ATS journal to celebrate the ATS's 50th anniversary has been a great experience. Interacting and reviewing the contributions of legends and up-and-comers alike. I already have a love for this industry, and it's only reinforced that.

I regret that the list of interviewees and authors within this celebratory journal is far from complete. Many prominent ATS contributors and influential tunnellers do not feature. Fortunately, the ATS will continue to provide a place where we can meet, learn, debate, and laugh. I hope to be around for the ATS100 anniversary to contribute like many of the legends have today. I'll be 83 and hopefully still sporting a hard hat and muddied boots."

Tom Roper, Engineering Manager, Acciona

"Congratulations ATS on 50 years.

The opportunities created for young engineers to network and learn through the ATS have been invaluable in my early career. I look forward to my continued involvement!"

Harry Buchanan, winner of the David Sugden Award 2021



"Congratulations ATS!"

Russel Connors, recipient of the 2017 David Sugden Award



Building the knowledge bank

By David Hake

There have been tremendous developments in tunnelling over the years in Australia. So, as the ATS turns 50, I thought it would be interesting to look back on something that has now been superseded by innovation.

In mid-1995, I was working on the North Western Sewer project in Melbourne and we had a compressed air tunnel. The compressed air lock was approximately 62 metres in length and comprised two sections, a 12-metre-long emergency air lock and a 50-metre-long personnel/material lock. Both sections had an internal diameter of 2.1 metres.

The 50-metre-long section was sized to suit a rolling stock muck train comprising four muck cars, a grout car and two segment cars. In-bye of the lock under compressed air conditions we used battery operated locomotives, and out-bye in free air we used diesel locomotives to move the rolling stock. This air lock was reasonably sophisticated with automatic doors, hydraulic rail stops and a hydraulically operated fold-down rail bridge, and a large operators panel in the tunnel out-bye.

The full tunnel crew and shift engineer would compress and complete their eight-hour shift in the tunnel under pressure, then decompress in the lock at the end of their shift, passing the time with a few hands of cards, some light reading or crafting caricatures of their mates to stick on the lock wall.



It's interesting to note that this was the last time this method of pressurising the tunnel was used in Australia for soft ground tunnelling below the water table. Since then, to improve safety and minimise worker exposure to hyperbaric conditions, only modern Earth Pressure Balance or mixshield TBMs or, sometimes, variable density machines have been used. These modern TBMs have in-built compressed air locks within the TBM shield for cutterhead access only.

The North Western Sewer Project – Tunnelling Section 3 was awarded the 1997 IEAust Excellence Award, Victoria Division, and was the last of its kind. I co-authored the technical story of the project at the 10th Australian Tunnelling Conference in Melbourne in March 1999.

We have come a long way to where we are today thanks to tunnelling innovations, and I can only imagine what the next five decades will bring.

David Hake is the General Manager Tunnelling for John Holland which is a Platinum Sponsor of the ATS. He has spoken at events, technical sessions and the triannual Australian Tunnelling Conference. He joined the ATS as an individual member in 2015 to help promote the industry, contribute to the development of tunnel engineers and encourage involvement in conferences, the ATS short course and the David Sugden Young Engineers Writing Award. He believes that sharing knowledge through ATS meetings and participating in the industry is important to help develop experience, strengthen relationships and provide an opportunity to help shape the future direction of tunnelling in Australia.



A couple of favourite memories

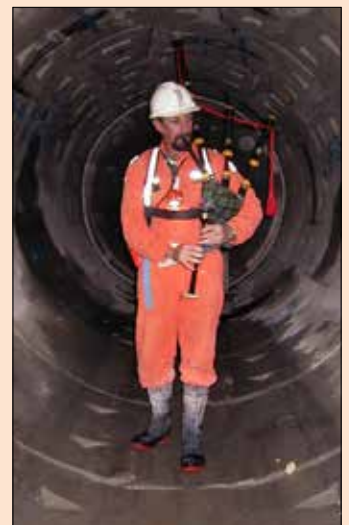
By Tony Peglas

Being a member of the ATS has enabled me to learn and stay current with the latest projects and emerging issues in the tunnelling industry. As the ATS National Austroads Representative, I have had the opportunity to contribute to updates to the Austroads Guide to Road Tunnels and the coordination of technical research projects to inform improvements in road tunnel practices.

Most importantly, being an ATS member has provided me with a platform for regular catch ups with industry colleagues, co-workers and friends, who have the same interest and passion for tunnels. I'd like to wish the Society, and all those who have guided and grown it over the last 50 years, a huge congratulations on this amazing achievement.

One of my favourite tunnelling memories comes from working on the S1 Sewer Tunnel in Brisbane back in 2000-2001. From time to time, one of the inspectors for Brisbane Water, Gordon Peden, brought in and practiced his bagpipes in the tunnel due to the 'amazing acoustics.' We used to joke that it was another reason why earplugs were an essential part of PPE!

Another favourite memory was during construction of the underground Y-Junction as part of the South East Busway in Brisbane in 2000. Most people don't know it exists because the stub tunnel on the right (for future light rail) has never been used and is hidden by architectural panels. I remember seeing ATS President Harry Asche standing in the middle of the junction, and this was the moment we realised just how large the cavern



actually was - approximately four and a half Harry's tall, and many more wide.

Tony Peglas is a Principal – Tunnelling at Aurecon and has been a member of the ATS since 2006. He sits on the Queensland Chapter Committee and has been the ATS National Austroads Representative since 2016.

Finding and sticking with tunnelling

By Ted Nye

I started my tunnelling career on the Melbourne Underground Rail Loop (MURL) around 1974. Working with a group of other engineers, geologists, surveyors and technicians, I installed instrumentation (including piezometers, multi-point extensometers, load cells, thermocouples, wire resistant and vibrating wire strain gauges) on temporary and permanent structural elements for tunnels and stations, and helped assess the data they collected.

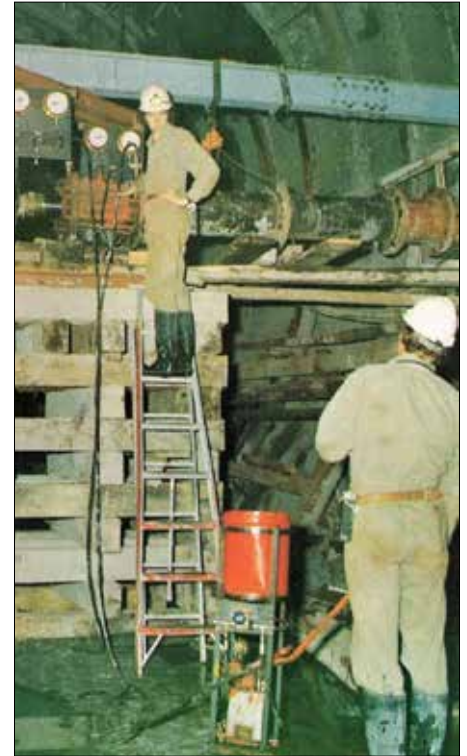
This experience was enhanced by running Finite Element (FE) analysis models (after drawing up and numbering the FE grids by hand and then getting coded sheets converted into punch cards!) to run on a main frame computer at Melbourne University (mentored by Dr Des Fitzgerald), to compare the FE results with the field monitoring data. I also got involved in setting up and monitoring large-scale plate bearing tests in the tunnels to compare the rock disturbance zones between TBM, road header and drill and blast excavation methods.

A few years of working on the MURL

project, combined with a year working in Hong Kong on existing networks of disused tunnels and slope stability, convinced me I should stick with tunnelling.

Fast forward to today and I'm still enjoying my tunnelling career. Most recently, in 2017 and 2020, together with Peter Prince (Transport Planner) and Dr Sam Lackey (now into Major Project Financing) as conference paper co-authors, I've been investigating an idea I first had in 1996, which is to build a rail tunnel across Sydney Heads*.

Ted Nye is a consulting specialist in underground engineering for transport related projects. He has been a member of the ATS for over 25 years and held many roles within the Society, including Chair of the 2014 Australian Tunnelling Conference in Sydney and Chair of the NSW Chapter. He says the ATS has provided a welcome means of networking within the industry, passing on and receiving knowledge and making long term friends and associations and should be much congratulated on its 50-year milestone.



*For more on this, please watch the presentation: Sydney Heads Rail Tunnel - a potential new rail corridor on YouTube: <https://www.youtube.com/watch?v=t70kd6eUMfl>



"It's been a fantastic adventure being part of the Australian tunnelling community for over 30 years. Starting with the Sydney Harbour Tunnel project in 1988, followed by Prospect to Pipehead water tunnel, SET 1B bus tunnel and the S1 sewer tunnel in Brisbane. Although challenging, there's a great sense of achievement having worked on these early projects.

In recent years I have enjoyed the camaraderie of being part of the ATS for almost 10 years helping to drive some important initiatives and so in some small way giving back to the tunnelling community.

One of my enduring memories of my time underground was finishing a night shift on the Sydney Harbour Tunnel and coming out of the muddy tunnel portal, under the Harbour Bridge, to look across the harbour to the bright Sydney city lights and Opera House – good times!"

Andrew Ridout, Independent Consultant



"Congratulations to the ATS for making it to the 50-year milestone! As a member of the 50th anniversary special journal editorial committee, I have enjoyed the opportunity to reflect on the history of the society over the last 50 years. The contributions of the ATS have made significant societal impacts both locally and globally. Looking forward to the next 50 years!"

Rachael McCarrison, Senior Engineering Geologist, WSP



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