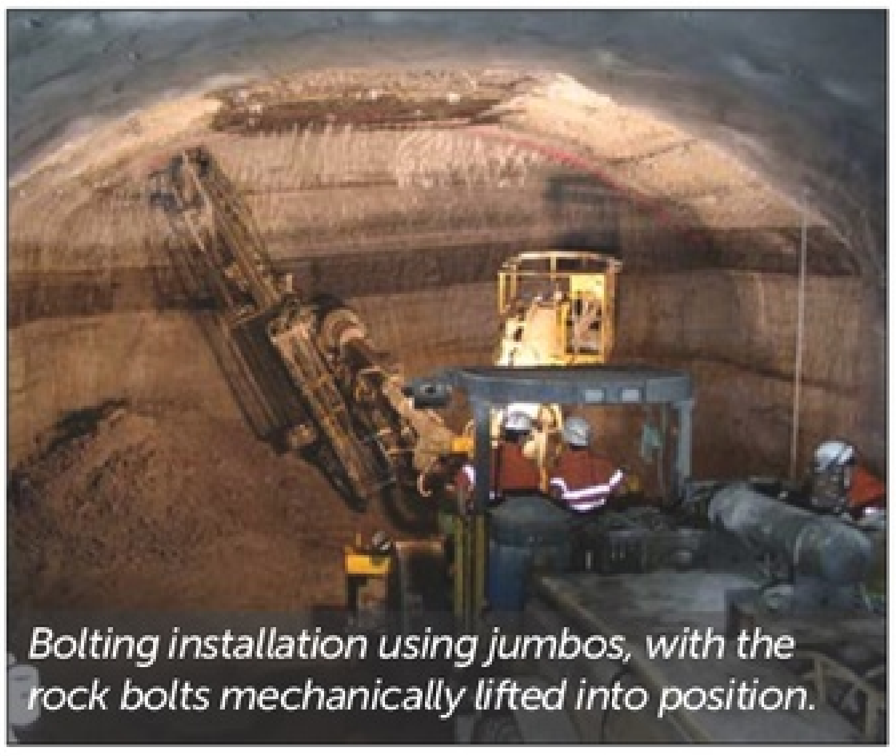
50 years of tunnel geotech in Australia

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



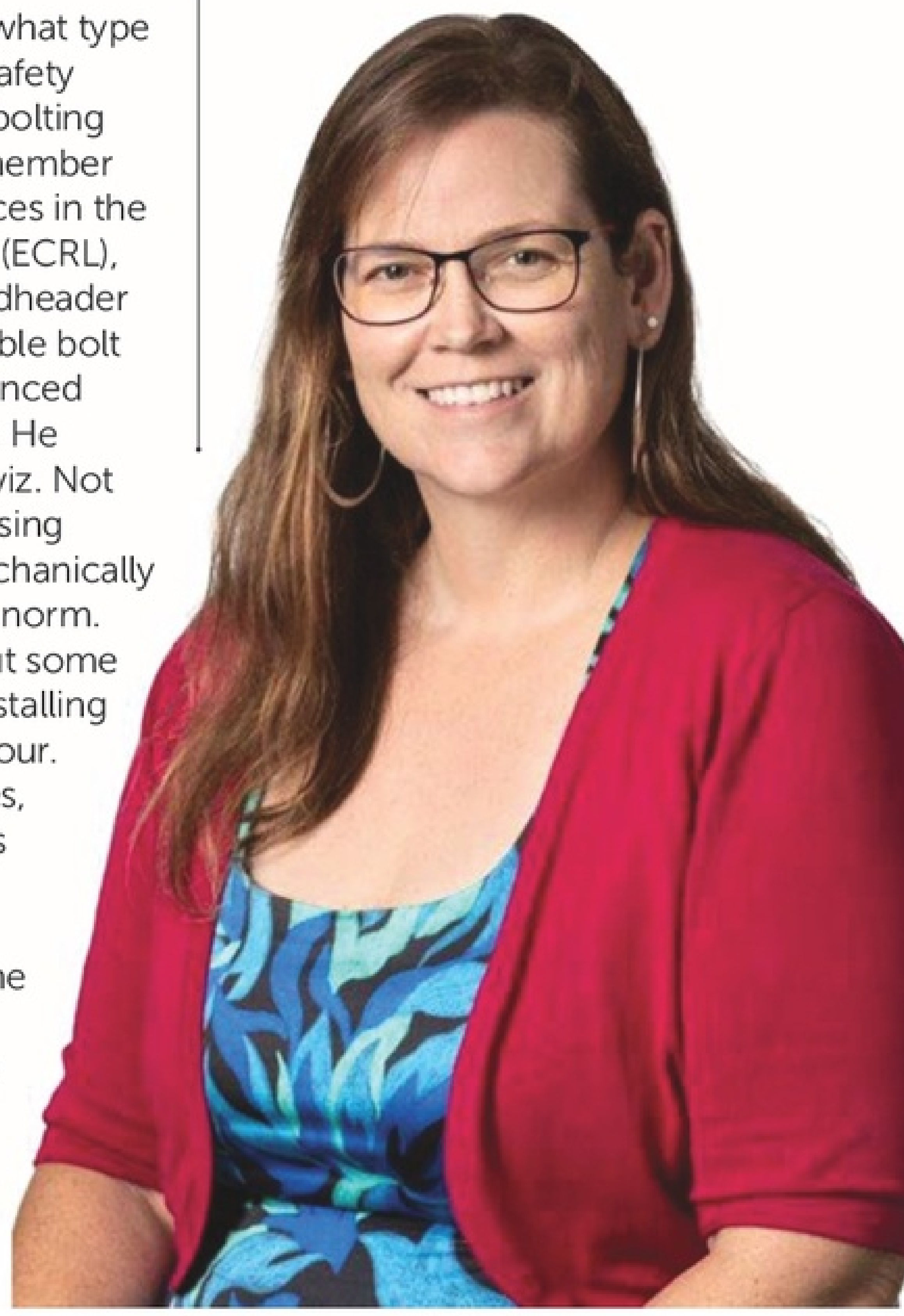
Bolting installation using jumbos, with the rock bolts mechanically lifted into position.

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 televiewer 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 televiewer data being provided for projects often doesn't reflect this. As the televiewer 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 televiewer unless the in-situ conditions suggest it may be something other than a joint. The televiewer 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.

References

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