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A&NZ JOURNAL

Journal of the Australian & New Zealand Tunnelling Societies

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Since 1990, TERRATEC's machines have been breaking production records all over the world. Most recently, one of two 6.56m diameter Earth Pressure Balance Tunnel Boring Machines (EPBMs) employed on the Dudullu-Bostancı Metro Line project, in Istanbul, completed an impressive advance of 19 rings in a single shift.

Equating to 26.6 meters of excavation in just 12-hours, the TERRATEC TBM worked non-stop – alternating between 20-minute mining and ring building cycles – to accomplish a new production record for a TBM of this size and class in Turkey.

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Cover photo:
M4-M5 Link Tunnels at Wattle Street Haberfield courtesy of WestConnex and Lendlease Samsung Bouygues Joint Venture

Executive Committee Members

President's foreword

To members, supporters and friends of the ATS,

Having only just returned from a few months abroad when work and the ATS did not occupy so much of my time, you suddenly realise how must is being achieved on the tunnelling front at home. You hear the highlights, a breakthrough here, another job has been awarded there, or another one commences. There is so much that is keeping all our key contractors, engineering houses and suppliers very busy right now. The statistics show that both Sydney and Melbourne are currently in the top 5 cities in the world for tunnelling activity (by expenditure). This is likely to continue for some time yet.

It was very pleasing to see so many ATS members and others involved in the Australian industry present at the ITA World Tunnelling Congress in Naples. Many present were actively involved in the ITA through Working Groups which are responsible for many of the technical documents produced by the ITA. I thank you all for your time and commitment in this very important endeavour.

From the General Assembly in Naples, we have a new ITA President in Jenny Yan from China. She will bring a new perspective to the role with a clear vision for the future of the international body. I also congratulate Arnold Dix being elected as one of four new Vice Presidents.

Jenny has been very supportive in the past of the activities of the ATS and she is especially pleased to congratulate us on being given the opportunity to host the ITA International Tunnelling Awards presentations and ceremony in 2020. This event will be held in conjunction with our National (Australasian) tunnelling conference late next year.

I look forward to seeing some Australian projects being considered for an award in 2020. The international recognition from these prestigious awards can be extremely valuable to all involved, clients, builders, suppliers and individual members. It is very pleasing to report that the ATS air quality working group is a finalist in this years awards under the category "Safety initiative of the Year". Kate Cole is to be congratulated on this achievement and we wish her all the best in Miami.

This is the last opportunity I have as your President to address you all. The ATS is in very good hands and I am confident that the new executive will continue to grow the organisation for the benefit of all members and supporters and importantly, our industry at large. It is indeed an exciting time to be involved in the tunnelling industry.

Thank you all for your support and encouragement, and as always, enjoy the read.

Ed Taylor,
President
Australasian Tunnelling Society

EDITOR'S NOTE

Please enjoy you latest copy of the journal.

I am particularly pleased to include a number of write ups from presentation held around the country at the different Chapters. Thank you all for your efforts in putting these together.

Tunnelling projects are busy throughout the country with many other projects planned or being developed. Here's to a bright future.

As always I am keen to receive any reports form members or supporting companies to be included in the journal – so please feel free to contact me

David Lees
ATS Editor

Sydney Northern Beaches Link

Beaches Link has been identified as a priority transport infrastructure project for New South Wales. The 2016-17 NSW Budget allocated $17.6 million for planning for the Western Harbour Tunnel and Beaches Link. The project, which has been estimated to cost at least $3 billion, will bypass up to 21 sets of traffic lights and slash travel times by about 40 minutes between Brookvale and the CBD. NSW Premier Gladys Berejiklian and Roads Minister Melinda Pavey have confirmed construction of the Northern Beaches Link Tunnel on March 16, 2017.

The possible procurement approach is thought of as a PPP. The government said motorists would almost certainly have to pay tolls to use both the Beaches Link and the Western Harbour Tunnel once opened. The NSW Government has also committed $77 million towards geotechnical investigations for the projects which started in April 2017 and involve the drilling of 235 boreholes across the combined route of the projects. Coffey and AECOM are conducting the investigations.

A road tunnel was first pitched for the northern beaches in the 1930s

Brisbane Metro

The $944 million Brisbane Metro bus project includes a new underground station at the Cultural Centre and a tunnel along Adelaide St in the CBD.

The new underground Cultural Centre station is to be located beneath the existing South Brisbane railway corridor, the property at 125 Grey Street, the intersection of Grey and Melbourne Streets, and the QPAC Green. An underpass of the railway corridor will connect the station to the existing South East Busway beside the BCEC. The new underground station is to connect to Victoria Bridge via a transition structure along Melbourne Street.

The station will include stopping bays for inbound and outbound metro vehicles and buses, and central through running lanes in both directions. Side platforms are proposed to be approximately 100 metres long and up to 5.5 metres wide. The platforms will be approximately seven to eight metres below surface level. The platforms will be designed to cater for pedestrian flow during peak times. They will include full height platform screen doors providing customer comfort as well as management and separation from the metro vehicles and buses.

Customer access will be provided to each platform by escalators, stairs and a lift. The escalators allow bi-directional peak hour management. The two station entries are proposed to be located at 125 Grey Street, at the corner of Grey Street and Melbourne Street. The station entries include surface level ticket gates to allow fare management. The station ground level concourse has a canopy structure extending the full width of the site, with provision for small retail tenancy spaces

A new tunnel under Adelaide Street will connect North Quay to the existing Albert Street bus tunnel near King George Square station, completing the grade separation and segregation of the busway corridor from general traffic. A tunnel portal and transition structure will be located at Adelaide Street, on the river side of George Street.

The tunnel will provide one lane in each direction for metro vehicles and buses. It is proposed to be about 13 metres wide, approximately 200 metres long and up to about 11 metres deep where it connects to the existing Albert Street bus tunnel and King George Square station. A 'hook turn' lane will be provided to allow inbound buses to access QSBS (i.e. buses would turn right from a left-hand lane).

Platform extensions will be required to the existing Eight Mile Plains, Upper Mt Gravatt, Griffith University, Buranda, Mater Hill, and Roma Street stations, to accommodate increased station activity. Modifications will also be required to the platform screen door locations at King George Square station. Existing entrances and exits to current stations will be re-used. DDA compliant access and ramps will be provided as required, whilst maintaining the existing entrances.

All existing busway stations will also be upgraded to include:

- new ticket stand-alone card interface devices on the platforms to facilitate off-board ticketing, i.e. 'tagging on' and 'tagging off'
- new passenger information displays to support the real-time bus management system and to inform customers of the stopping bay approaching metro vehicles and where buses would depart from
- new Brisbane Metro branding (e.g. painting, signage).

However, the project will be delayed again, lord mayor Adrian Schrinner has announced, after the state government required a planned underground station at the Cultural Centre to be moved. The three contractors who had put in for the Brisbane Metro Cultural Centre project would have spent about $6 million each on their bid, $3 million of will be contributed by the council.

Cross River Rail Project

The contract to build Brisbane's Cross River Rail's 5.9km twin tunnels and four new underground stations has been finalised with Pulse, the consortium selected as the preferred proponent in April. The Pulse Consortium is comprised of CIMIC Group companies, Pacific Partnerships, CPB Contractors, and UGL with international partners DIF, BAM, and Ghella Investments & Partnerships.

Work includes a 10.2-km-long railroad tunnel from Dutton Park to Bowen Hills, including a 5.9-km-long, twin-bore crossing of the Brisbane River. Four new underground stations will also be built.

A joint venture of BAM International, CPB Contractors and Ghella Pty Ltd. will handle design and construction, while UGL will maintain the infrastructure for 24 years. BAM PPP-PGGM, Pacific Partnerships, Ghella Investments and Partnerships and DIF will provide equity funding.

The Project's delivery remains on track for construction completion by 2024, after which a detailed commissioning and testing program will begin.

Cross River Rail will enable the extra network capacity required to operate higher frequency public transport that connects with other services and supports other network growth projects.

This will help ease the pressure of road congestion, making Brisbane and the whole of South East Queensland even more liveable.

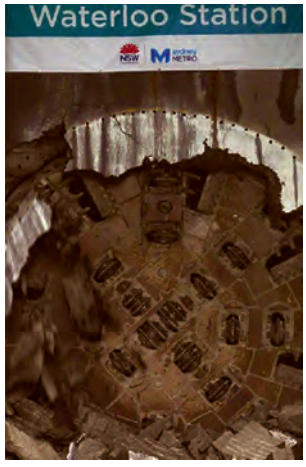
Sydney Metro

Four Herrenknecht double-shield, hard-rock TBMs have already completed over half of the 31km of 6m i.d. tunnel for Sydney Metro City & Southwest.

One of the project's five Herrenknecht TBMs has already broken through into the new Crows Nest Station site.

TBM Mabel's cutterhead broke through a wall of rock at the new Crows Nest Station site after tunnelling about 3km from Chatswood. Since launching in February this year, TBM Mabel has excavated about 290,000 tonnes of sandstone and shale. Mabel will spend a few weeks undergoing maintenance before being re-launched at Crows Nest and tunnelling towards the next future Sydney Metro station at North Sydney.

TBM Mabel and partner machine, Wendy, are building 6.2km of twin tunnel which will link the recently opened North West Metro at Chatswood to the harbour's edge at Blues Point. They are two of five Herrenknecht TBMs building the 15.5km, 6m i.d. twin railway tunnels between Chatswood and Marrickville. The TBMs are purpose built, with four double-shield, hard-rock TBMs designed to bore through



Sydney's hard sandstone, whilst a mixed-shield slurry TBM will excavate through the under-Sydney Harbour ground conditions, which is now underway. Mixshield slurry TBM, Kathleen has passed its final inspection and has launched 30m below ground from Barangaroo to dig the historic 1km long rail crossing deep under Sydney Harbour.

The machine is expected to tunnel through clay, silt and sediment under the harbour.

After building the first tunnel, Kathleen will have her cutterhead and main section lifted out at Blues Point and placed on a barge to return to Barangaroo. The machine's support trailers will be pulled back to Barangaroo inside the first tunnel.

Kathleen will then build the second tunnel under Sydney Harbour after that, the whole TBM will be retrieved at Blues Point and taken away by barge.

This specialised TBM is named after Kathleen Butler, who played a vital role in the construction of the Sydney Harbour Bridge as the technical advisor to legendary engineer John JJC Bradfield.

Slurry from the TBM will be pumped through pipes to a treatment station at Barangaroo where water will be extracted and recycled, and spoil dried before being barged to be used on road projects and building sites.

The first tunnel from Barangaroo to McMahons Point is expected to take up to three months to dig to depths of up to 40m below the harbour.

Tunnelling contractor, John Holland/CPB/Ghella was awarded the $2.81bn contract in June 2017. The current schedule sees the tunnelling contract conclude in 2021.

The second stage of the metro line from Chatswood to the CBD, and onto Sydenham in the south, and Bankstown in the west, is due to be completed by 2024 at a cost of up to $12.5 billion. The government also expects to start construction on a $20 billion metro line from Sydney's CBD to Westmead near Parramatta next year, and complete a metro line from St Marys to the new $5 billion Western Sydney Airport at Badgerys Creek by 2026.

Melbourne Metro

On 5 June 2019 the first piece of the TBM, named Joan for Victoria's first female premier Joan Kirner, was lowered into the North Melbourne station box.

The TBM will travel from North Melbourne Station to what will be the start of the new tunnel in Kensington.

The four gigantic tunnel-boring machines that will be put to work beneath the CBD this year have been named after "groundbreaking women" following a public naming competition which garnered 1100 suggestions.

Three other machines are being shipped from overseas and are due here soon have been named after Meg Lanning, captain of the Australian women's cricket team; Millie Peacock, Victoria's first woman MP; and Alice Appleford, who won the military Medal for Gallantry in World War One.

Cross Yarra Partnership is looking for drivers to operate the massive TBMs that will dig the Metro Tunnel. Six trainee drivers will be hired, all from Victoria. The trainees will take part in a world-class accelerated training program led by experienced TBM operators, tunnellers and engineers. Training will include a cutting edge TBM simulator that provides a computer-generated replica of the control panel inside a TBM and recreates the geologies and operating conditions underground.

Being a TBM operator requires an appreciation of mechanics, a knowledge of civil engineering and an understanding of geology. Inside this mobile machine, measuring in excess of 8 meters in diameter, sits the operator who uses screens as an aid to constantly monitor the trajectory and driving progress of the tunnel. The operator has a vital role on the construction site.

The successful TBM driver candidates will be required to have an appreciation of mechanics, knowledge of civil engineering and an understanding of geology.

Construction has begun on the Melbourne Metro Tunnel's Anzac Station, with contracts awarded for the supply of Australian-made steel and concrete to create the roof. AUSREO has won the contract to supply more than 3,800 tonnes of steel reinforcement for the roof and Holcim will supply 15,000 cubic metres of concrete for the roof slabs.

An acoustic shed will be built over the northern section of the site to minimise noise and dust. This area will also serve as the launching site for the TBMs that will head towards the eastern tunnel entrance.

When finished, Anzac Station will improve access to the employment hub around St Kilda Road, with travel time savings of up to 25 minutes for passengers on the Cranbourne and Pakenham lines. People using the Sunbury line will cut up to 20 minutes off their journey, while commuters on several other lines will save up to 10 minutes to the same destination.

Major work is also in progress across multiple Metro Tunnel sites. At South Yarra, demolition of the William Street bridge was completed Wednesday 10 April as part of initial work to construct the Metro Tunnel's eastern entrance. Workers are now busy installing 68 concrete piles to provide structural support for the realignment of the tracks, plus construction of the roof slab for the entrance.

Meanwhile, the Level Crossing Removal Project has been forging ahead with work during the blitz. Workers on the Frankston Line have prepared signalling equipment and utilities for the Carrum level crossing removal.

On the Mernda line, around 200 people worked around-the-clock for six days to demolish Reservoir station and begin piling for the foundations of a new rail bridge that will remove the dangerous and congested level crossing.

While the major closures are underway through the south-east, specialised signalling cabling has been installed in the City Loop, signalling components have been upgraded between Flinders Street and Richmond stations, and steel structures are being built around Richmond ready for the installation of new overhead wiring.

The station currently being bored under Melbourne's state library is starting to come together with the first station cavern now fully connected.

The roadheaders have completed the station caverns and underground passenger connections under Swanston Street, near Franklin Street, for the new State Library Station.

Seven roadheaders will be used in the CBD as part of the project – four for State Library Station and three for Town Hall Station. Each weighs 118-tonnes, is 15-metres long and is lowered underground in separate pieces, before being re-assembled underground.

The road headers have dug out more than 20 per cent of State Library Station, with excavation expected to be finished by late-2020.

As construction continues on the Metro Tunnel, Melbourne-based TTM Rail has been awarded the $1.6 million contract to fit out two X'Trapolis trains for High Capacity Signalling (HCS) to be tested on the Mernda Line.

Work has already begun to prepare the track between Epping and South Morang stations for testing in 2020.

A 200-metre long tunnel being built beneath Swanston Street, forming a key section of the twin rail tunnels and passenger underpasses at the new station is starting to take shape, with the underground station's first platforms being

carved out.

Two separate access shafts being excavated at Franklin and A'Beckett Street have now been joined underground via the new tunnel.

The State Library is one of five underground Metro Tunnel stations being built. The cavern is set to be finished by late next year, with 20 per cent of it excavated so far. Another three access shafts for the station are at earlier stages of excavation. Piling is underway at a third shaft on the corner of La Trobe and Swanston Streets with a roadheader still yet to be launched. A fourth shaft is at the western side of Franklin Street and a fifth on Little La Trobe Street near Literature Lane.

The tunnels beneath the CBD will be built in a "trinocular" design, meaning there will be three overlapping tunnels built – a complex design required for Melbourne's challenging geological conditions.

An extra three roadheaders will also be used to dig out the Town Hall station. The 15-metre long machines are lowered underground in separate pieces, before being reassembled inside the tunnel.

Meanwhile the cost of the Victorian government's flagship $11 billion infrastructure project, the Melbourne Metro rail tunnel, may have blown out by as much as $2 billion. Stakeholders involved in the mega project are warning of delays and major cost blowouts amid claims contractors have encountered unexpected problems including geological issues. The costs are expected to be worn by the consortium Cross Yarra Partnership (CYP), led by listed construction giant Lendlease, John Holland Group and Bouygues Construction Australia, not the state government.

The Metro Tunnel will run under the city between South Kensington and South Yarra.

Melbourne Airport Rail Link

Airport trains could be directed through the new $11 billion Metro Tunnel, Premier Daniel Andrews has said.

The Premier has revealed the airport rail project was unlikely to be completed until 2031, in contrast with previous claims that the project could be finished by 2027.

A Heads of Agreement has been signed by the state and federal governments locking in a $5 billion commitment from both towards the rail project.

However the $5 billion for airport rail would be a "grant" that would not rely on funding models such as value capture, which leverages money from private development. The whole project is tipped to cost $8 billion to $13 billion.

Exactly how the airport trains would reach the city is not yet known. The government has so far indicated the trains would stop at Sunshine station, which would become a "super hub".

A private consortium wanting to build the airport rail line, which includes Melbourne Airport, Southern Cross Station, Metro Trains and IFM Investors, plans to start building it by next year and finish seven years later.

WestConnex

M4 East is complete, New M5 is due to be complete next year and M4/M5 Link is underway. Under future plans, WestConnex will connect to the Western Harbour Tunnel at an underground interchange at Rozelle.

Sydney now has more kilometres of toll roads above and below ground than any other city in the world – a situation that is set to grow significantly over the next five years.

By 2023, the city will have 12 toll roads including the final stages of WestConnex and NorthConnex. A year later, the first stage of an extension of the F6 motorway in Sydney's south is due to open at a cost of up to $2.6 billion, followed by the Western Harbour Tunnel and Beaches Link tollway.

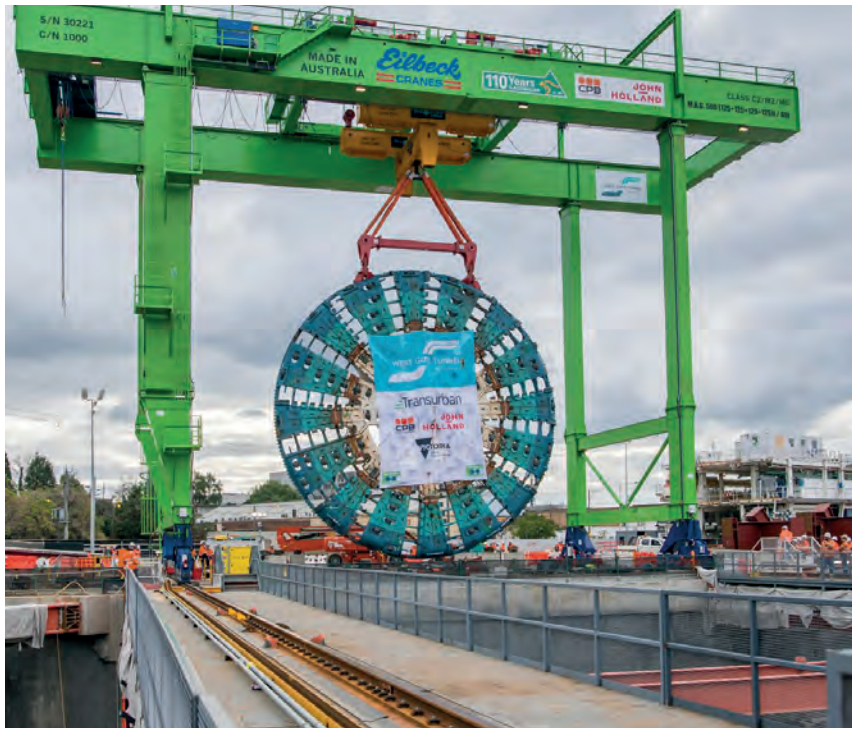
The New M5 tunnels are being built by CIMIC's CPB Contractors and Dragados. The twin tunnels will be 12.5 metres wide and drained not tanked.

West Gate Tunnel Project

The West Gate Tunnel Project (WGTP) has gained momentum and made significant progress throughout 2019. The project will provide a vital alternative to the West Gate Bridge, allow for quicker and safer journeys and remove over 9000 trucks from residential streets in the inner west.

The project is a partnership between the Victorian Government and Transurban and is being built by a joint venture between CPB Contractors and John Holland. The project is managed on behalf of the Victorian Government by the West Gate Tunnel Project, Major Transport Infrastructure Authority.

The project spans three geographic zones covering the Port to City Zone (the CBD end), the Tunnel Zone (including the portals at each end) and the West Zone (along the West Gate Freeway from Williamstown Road to the M80 Interchange).



Northern Portal

At the northern portal construction site in Footscray, the large cut and cover structure, 330m long x 40m wide x 22m deep at the launch face, has really taken shape. Permanent works on the concrete structure commenced around the clock from late March 2019, with continued reinforced concrete works and temporary strutting system removal nearing completion at the city end of the launch ramp. The structure is fully tanked for water tightness with approximately 600 wall piles and 400 base slab tension piles incorporated to prevent uplift.

The focus was to complete the front 120 metres of the box first to allow for the assembly of the tunnel boring machines (TBMs). This was followed with the conveyor transfer structure and vertical loop take-up, before moving into the open ramp structures. Following the launch of the two TBMs, the horizontal elements of the box, such as the road deck, ventilation structure and roof slab, will commence in parallel.

North Yarra Main Sewer Diversion

The North Yarra Main Sewer (NYMS) is a 2.6 metre circular brick-lined sewer constructed in the 1890s. The sewer transfers flows from Melbourne's north-eastern suburbs to theWestern Treatment Plant in Melbourne. The sewer is a critical asset within the Melbourne Water sewer network, conveying around 20% of Melbourne's sewerage with no upstream diversions or redundancies available. The existing sewer was required to be diverted due to a conflict with the WGTP main tunnels. The diversion required 636 metres of pipe-jacked diversion in two legs; 212 metres to the upstream shaft and 424 metres to the downstream shaft. Both using a 3 metre diameter slurry pipe-jack TBM and glass reinforced plastic lining.

The construction of the shafts required extensive traffic management and diversions, involving comprehensive community and business engagement.

With typical Peak Dry Weather Flows in the order of 3300 litres per second and Peak Wet Weather Flows up to 7300 litres per second, it was proposed to complete the diversion as a live sewer connection instead of higher risk over-pumping with these flows. A detailed sequence of containment and bypass was completed successfully to divert the sewer. The shafts have now been backfilled and reinstatement was completed in mid-2019.

Instrumentation and monitoring and groundwater recharge

The project requires extensive instrumentation and monitoring (I&M), particularly for ground, building and excavation movements and groundwater level monitoring. To manage the groundwater levels and potential movement of contamination in the brownfields locations at the portals and along the tunnel alignment, groundwater recharge is also employed at many key locations.

The full I&M is linked through a web-based software system to capture information in real-time from the automatic theodolites, vibration monitors and groundwater level sensors. The groundwater recharge is also linked to the system to ensure stability of the groundwater regime. The system is installed and operational, providing real-time information to the various excavation teams across the project.

TBMs & tunnelling hub site temporary works

The two 15.6 metre diameter TBMs, the largest in the Southern Hemisphere,

are being assembled to commence tunnelling. TBM 1, named Bella, will launch first, closely followed by TBM 2, named Vida. The two TBMs weigh over 4,000 tonnes each and have been assembled using the project's 250T and 500T gantry cranes.

The 2 x 2500 tonne per hour conveyor systems have been installed from the spoil shed on the neighbouring tunnelling hub site through to the TBM launch box, including an intermediate transfer tower to align the conveyors for a bridge crossing of Somerville Road to reach the spoil shed. Trucks will enter the spoil shed and be loaded by 50 tonne excavators and return to the road network via a newly signalised intersection.

All other launch facilities including grout plant, high voltage reticulation, compressors and air chillers, water chillers, grout and bentonite plants are all installed and commissioned.

Southern Portals – Inbound Southern Portal and Outbound Southern Portal

At the inbound southern portal, a land-locked triangular site between the West Gate Freeway, Williamstown Road and the Williamstown Road off-ramp, extensive ground preparation works are underway, including grouting for groundwater cut off and piling for a soldier piled wall excavation. Capping beam and excavation works have commenced and are ongoing.

At the outbound southern portal, excavation and construction of a 12 metre high soil nail and shotcrete wall adjacent to the West Gate Freeway to reach rock head is underway. Excavation in rock is now progressing using excavators with hammers, supported by rock bolts and shotcrete. Production excavation is well underway.

Both excavation areas require close coordination with the West Zone teams and utility companies due to their close proximity to overhead power and buried fuel and gas lines.

In the West Zone, extensive road widening is underway, with installation of footings for new footbridges, new monopoles for the overhead high voltage transmission, and ongoing noise wall installation. This work has stretched the full length of Williamstown Road to the M80 interchange.

In the East Zone utility diversions along Footscray Road have been occurring to allow for the recent milestone of the first major traffic diversion. This major movement of traffic will enable commencement of piling for the two elevated roadways which will run the full length of Footscray Road before turning and crossing the Maribyrnong River via new bridges to get to the northern portal. Piling works have also commenced in the river, along with extensive precast driven piling near the CityLink connections closer to the city.

Burrawang to Avon Tunnel

WaterNSW is investigating a suite of options to improve environmental outcomes, provide certainty and security of water supply to its customers and all whilst meeting the projected demand from Greater Sydney's future population growth.

The team are currently looking into the feasibility of the Burrawang to Avon Tunnel as one of the preferred options to meet all of these objectives, including better outcomes for the natural environment. The Burrawang to Avon Tunnel proposal is the final piece in completing the NSW Government's decade long strategy for restoring river health and protecting environmental flows in the Shoalhaven.

The current proposal is to design and build a 20 kilometre tunnel from Fitzroy Falls Reservoir to Avon Dam with an indicative carrying capacity of 1800 megalitres per day. The tunnel would protect the Illawarra from exposure to drought or asset failure, provide a secondary source of raw water supply to Greater Sydney and alleviate future stress on the Warragamba Dam catchment.

To improve network resilience, the project will also consider additional methods of supplying the Illawarra Water Treatment Plant, particularly in drought. Alternatives include an 'off-shoot' tunnel to connect the proposed Burrawang to Avon Tunnel to Sydney Water's Illawarra Water Treatment Plant, and infrastructure to access deeper water in Avon Dam that is currently unavailable for supply. These options will provide greater certainty in water quality and the security of water supplied to the Illawarra, and by effectively increasing the available storage within the dam by 65 gigalitres.

As part of WaterNSW's commitment to support the NSW Government's 'NSW Pumped Hydro Roadmap', the feasibility of a hydropower generation plant will be a key part of the development of this project.

Project schedule

2018 - 2020 – Early investigation and concept design phase
2019 - 2020 – Environmental assessments undertaken
2020 - 2020 – Business case development

Snowy 2

Valued at U.S. $3.6 billion, a contract for the civil and electromechanical works on the Snowy 2.0 hydro project went to the Future Generation joint-venture, which is 65% owned by Italy's Salini Impregilo S.p.A and its U.S. subsidiary Lane Construction. Australia's Clough Projects Pty. has the balance.

Owned by Snowy Hydro Ltd., the project includes around 27 km of 10-m-dia, concrete-lined tunnel between the existing Tantangara and Talbingo reservoirs, both south-west of Cambera.

With 350 GWh of storage and 2,000 MW installed capacity, the project will allow Australia to smooth out the flow of the country's increasing share of wind and solar generation, being installed to replace coal plants.

A roughly 17-km-long headrace tunnel from the high level Tantangara reservoir will lead to a 550 m drop into a planned power house, which will be excavated about 1 km below ground. From the powerhouse and transformer halls, both about 190 m long, water will flow though a roughly 10 km tailrace tunnel to Talbingo.

Government-owned Snowy Hydro already has nine hydro power plants, including two pumped storage installations in the area totaling 4,100 MW

Auckland City Rail Link

Auckland's $4.4bn City Rail Link (CRL) has been awarded to Link Alliance JV to build the project's main stations-and-tunnels programme. The 3.45km of twin tunnels will be built at depths of up to 42m below the city centre using a 7m diameter TBM, with roadheaders and cut and cover sections for the connections.

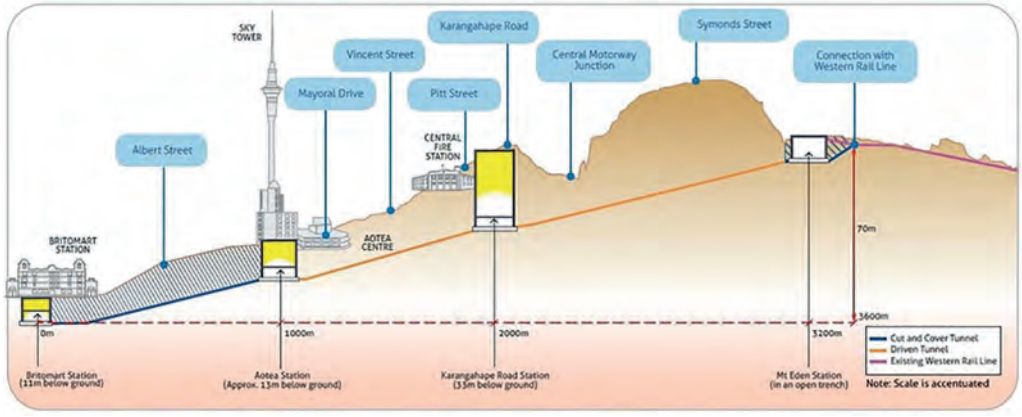
Link Alliance include Vinci Construction Grands Projets S.A.S,, Downer NZ Ltd, Soletanche Bachy International NZ Limited, WSP Opus (NZ) Limited, AECOM New Zealand Limited and Tonkin+Taylor Limited.

Signing the Project Alliance Agreement (PAA) clears the way for the three construction companies and three design companies in the Link Alliance, together with CRL Ltd, to start work building two new inner-city underground stations, upgrading the existing Mt Eden station, and completing tunnel construction. It is the single biggest programme of work for CRL, known as the C3 contract.

The signing follows CRL Ltd's announcements last April of the Link Alliance as its preferred bidder, and details of a $1bn increase in the project to $4.4bn after a rigorous and comprehensive review of project costs. The project's two sponsors – The Crown and Auckland Council – subsequently approved CRL Ltd's request for additional funding. To ensure project momentum was not lost, the Link Alliance began work on a $75M Early Works Contract while commercial and legal negotiations continued to finalise the PAA.

Construction of three smaller sections of the project at lower Queen Street/ Britomart and north Albert Street in the city centre and utility-based work at Mt Eden are already underway.

The project is scheduled for operation in 2024.



Central Interceptor Project

Construction is set to begin on a $1.2 billion tunnel that aims to reduce Auckland wastewater overflows, with the signing of a construction contract.

The so-called Central Interceptor will run for 13km between Western Springs and the Māngere Wastewater Treatment Plant. Auckland Council's water utility body Watercare will work with infrastructure firm Ghella Abergeldie Joint Venture to deliver the project by 2025.

At 4.5m in diameter, the project will be Auckland's largest wastewater tunnel and the biggest wastewater project ever undertaken in New Zealand. The tunnel is expected to reduce wastewater overflows in the central city by 80 per cent. The largest wastewater project in New Zealand, the tunnel will stretch over 13 kilometres from Western Springs to the Māngere Wastewater Treatment Plant, collecting wastewater along the way via sewers and drop shafts. The Grey Lynn Tunnel, a 2-kilometre long extension has also been awarded to the JV as part of the construction contract. Mobilisation will start in May 2019 and the whole project is expected to be completed by 2025.

The project will greatly benefit Auckland and the community by providing additional wastewater capacity to accommodate the growing city and help reduce the volume of wastewater overflows, so that everyone can enjoy clean waterways, beaches and estuaries.

The central wastewater network currently overflows to local waterways and the Waitematā Harbour at more than 100 locations and to the Manukau Harbour at 14 locations. The Central Interceptor will run underground from Western Springs to the Māngere Wastewater Treatment, collecting wastewater along the way via link sewers and drop shafts. The Central Interceptor will address wet weather overflows by collecting the wastewater and stormwater from these overflow points and transporting it to Māngere for treatment.

It will cross Manukau Harbour about 15 metres below the seabed and along a route connect to the existing wastewater network, which will divert flows and overflows into the tunnel.

While the tunnel is being built Watercare plans to deliver further projects in the area such as separating stormwater and wastewater pipes. The largest of these projects is the Grey Lynn wastewater tunnel which is a 2km extension of the Central Interceptor.

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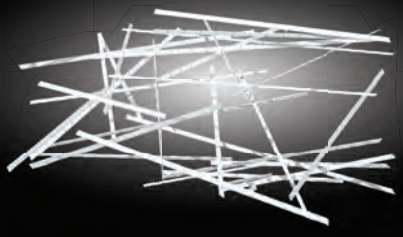

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Save the Basin

Save the Basin has expressed its opposition to a second Mt Victoria road tunnel. It appears from the information provided yesterday that such a tunnel would proceed only late in the first decade, subject to a detailed business case.

This makes a new Mt Victoria road tunnel seem increasingly unlikely, as all the parties presenting the announcement emphasised the priority of mass transit and the need to move beyond motorways. Let's give the good stuff a chance to work first, and look at whether we need new roading only after that.

It is understood the plan will be presented in two 10-year "phases", with the first phase to include building a second Mt Victoria tunnel, and Basin Reserve roundabout changes. The second phase would include a proposal to trench SH1 under Te Aro, between the Mt Victoria and Terrace tunnels.

The Terrace tunnel would also be reconfigured so the lanes were changeable, meaning two of the three lanes would go in one direction in the morning, and in the other direction in the evening.

Hunua 4 project

Microtunnelling has started under some of Auckland, New Zealand's busiest roads, as part of Watercare's Hunua 4 project.

A Herrenknecht microtunnel boring machine (MTBM), known as Amiria, has started its first drive of a 3km journey. The MTBM is being used as part of the NZ$400 million (AU$378 million) project, which began in 2012, to construct a pipeline – Hunua 4 – from Manukau City to Auckland.

The name of the MTBM was selected as part of a competition with the children at Starship. Amiria, is a te reo Maori version of the name Amelia, which means hard-working or industrious. This name is suitable as two of the drives are through 2.5km of basalt in the Auckland Volcanic field. The first drive is expected to be completed mid-year.

Tunnel running under Waitemata Harbour

Once again the Government is considering a tunnel in the Waitemata Harbour. For the past 60 years, the Auckland Harbour Bridge has been the main connection between the North Shore and Auckland's city centre. NZ Transport Agency says traffic at the approaches to the bridge at morning and afternoon peak periods are at capacity with heavy vehicle use on the rise. Heavy commercial vehicle use had increased 30 per cent over five years and was now approaching 11,000 movements on a weekday. However, the structural capacity of the bridge has been maximised and with projected growth looming the transport company is looking into multiple options.

Three separate transport options have been outlined in an NZTA report but even if one is decided upon, work won't start until the 2030s.

- Build a tunnel for light rail only.
- Build a tunnel for light rail and road access.
- Or, do nothing.

The report goes on to say when discussing the three options that there was no inclusion of heavy vehicle restrictions but added restrictions would likely be added in the future to manage the longevity of the harbour bridge.

The best option to reduce traffic in the city at morning peak times was a combination of road pricing and light rail, the report said.

"A light rail only crossing combined with road pricing delivers the best outcome for the city centre in terms of fewer cars entering the city centre during peak traffic times."

A road crossing with pricing would result in 3500 more vehicles entering the city centre during peak AM hours, compared to the light rail crossing.

The report shows predicted congestion around a combined road and light rail crossing on the Waitemata Harbour That would work against policies to reduce car trips and support a shift from private vehicles to more efficient models of transport.

Mumbai Metro Breakthrough

In early-August, the Hindustan Construction Company (HCC) – Moscow Metrostroy (MMS) Joint Venture celebrated the breakthrough of its 6.68m diameter TERRATEC hard rock TBM, named 'Vaitarna I',on Mumbai Metro Rail Corporation Ltd's (MMRCL) Line 3 project, in India.

The major milestone saw HCC-MMS JVcomplete the 3.82km southbound running tunnel between Chhatrapati Shivaji Terminal (CST)and Mumbai Central stations and become the first contractor on the project to finish an entire section of tunnel for one of the line's seven contract packages.

With production rates of up to 24m per day (holding the production record for the project), the TBM tunnel was driven via NATM station boxes at Kalbadevi, Girgaon and Grant Road, at an average depth of 20m. It was successfully completed on schedule despite numerous geological and logistical challenges, including the tunnel's proximity to the ocean, tunnelling through reclaimed land, congested working areas and excavating beneath some of the oldest buildings in the city, many over a century old.

"The HCC team completed this operation in a single drive, boring through geology consisting of basalt, breccia and tuff and reclaimed sand with negligible Settlement," said Ravi Ranjan Kumar,MMRCL's Chief Project Manager for UGC-02."Most of the tunnel alignment is under the oldest and most densely populated area of south Mumbai with many dilapidated residential buildings. The performance of the TERRATEC dual-mode hard rock TBM in this geology was highly satisfactory and we now look forward to the similarly successful completion of TBM 02 'Vaitarna 2'."

The machine is one of two new TERRATEC dual-mode TBMs being used on contract UGC-02, which was awarded by MMRCL in July 2016. Five other TERRATEC TBMs are also achieving good progress on the new 33.5km-long underground corridor.

The single shield TBMs are equipped to operate in either Open or Closed modeand have robust hard rock cutterheads that are mounted with heavy-duty 17" disc cutters, which are interchangeable with ripper tools, and feature large bucket openings that provide a 10% opening ratio.

Other state-of-the-art features include 2,000kW Electric Variable Frequency Drives – that allow the cutterheads to cut efficiently in harder rock zones at maximum speeds of 7rpm and deliver an exceptional torque of 8,500kNm to cope with more fractured zones of ground along the alignment – as well as active shield articulation and built-in two component backfilling grout systems.

When complete, Mumbai Metro's much-anticipated Line 3 will be the first underground metro line in the city. The 33.5km-long line will connect Cuffe Parade business district in the far south to the Santacruz Electronics Export Processing Zone (SEEPZ) in the north-central with 26 underground and one at-grade station.

Construction of the line is divided into seven tunnel-and-station packages that were awarded to five contracting joint ventures in 2016. These five contractors have deployed a total of seventeen (17) TBMs with TERRATEC being the lead TBM supplier on the project with a 41% market share.

To date, the seven TERRATEC machines have completed 65% of the 22.6km allocated to them – signifying almost half of the total 54km of tunnelling on the Line 3 project – and hold the production records for best day and best month on the project.

Chennai Airport tunnel proposal

Chennai Airport, India, has appointed Singapore-based Meinhardt as a consultant to examine a proposal for the construction of a tunnel inside the airport. Meinhardt is expected to provide suggestions and recommendations in approximately six months.

The tunnel will connect the satellite terminal located near the remote bays with an integrated terminal that is currently being constructed.

There will be two tunnels at the airport. One will be used for transporting passengers while the other will be used to move baggage from the integrated terminal to the satellite terminal.

The new integrated terminal is being built as a part of the airport's second phase of modernisation work.

An AAI official has been quoted by The Hindu as saying: "Soon after the consultant finishes the feasibility study, a new contractor will be appointed for building the tunnel and the satellite terminal. "It will be quite a challenge to build it in a fully functional airport, but we can take it up in parts and finish the construction. For a start, the consultant will first do soil tests to identify the right location for the tunnel. The satellite terminal will be compact and a small one with basic facilities for passengers."

Foundation stone laid for Sela tunnel project

Prime Minister Shri Narendra Modi has laid the foundation stone for the Sela Tunnel Project in Arunachal Pradesh. The Project (BRO) will be completed in the next three years. The project allows for the widening of an existing single lane road to a National Highway double lane. The project also includes construction of two tunnels of length 475m and 1790m each crossing the Sela pass (Sela-Chabrela ridge) then meeting the existing Balipara-Chaudur-Tawang road on the Nurarang side. The altitude of the new alignment will vary between 3352,8 m (11,000 feet) and 3657,6 m (12,000feet). Once completed this would result in all weather connectivity to Tawang and areas beyond.

NHSRCL launches tender for undersea rail tunnel in India

National High-Speed Rail (NHSRCL) has launched a tender process to build an undersea rail tunnel for the Ahmedabad-Mumbai bullet train project. The 21km-long undersea rail tunnel will stretch from Bandra Kurla Complex to Kalyan Shilphata in the state of Maharashtra. It would include a 1.8km section on the sea bed and 7km under the Thane creek. The remaining section will be built under mangroves on the two sides of the creek.

In addition to building the tunnel, the scope of works includes testing and commissioning double line high-speed railway using a TBM and NATM for the project. The works are expected to be completed within three and a half years.

A geotechnical investigation to construct the undersea tunnel area was completed last year. The survey was carried out by a joint team comprising engineers from NHSRCL, RITES and Japan's Kawasaki Geological Engineering.

The 508km-long Ahmedabad-Mumbai bullet train project is scheduled to become operational in 2022.

Karnaphuli tunnel excavation begins

Karnaphuli Tunnel is an underwater expressway tunnel in the port city of Chittagong, Bangladesh under the Karnaphuli river. The tunnel, which will go under the Karnaphuli at the Naval Academy point in Patenga and connect with Anwara on the other side, will enhance the Dhaka-Chattogram-Cox's Bazar national highway network. A TBM used for excavation has been imported from China.

The economy of Chattogram is considered would almost double once the tunnel is constructed. A new township will develop on the other side of the Karnaphuli once the construction of the tunnel completes, linking the port city with Anwara upazila. The tunnel would strengthen the role of Chattogram as the centre of communications system, said Mahbubul Alam, president of the Chittagong Chamber of Commerce and Industry.

The total length of the proposed tunnel will be about 9.3km, 3.4km under the river, an approach road of 5.25km and 727m of over-bridge.

The cost of the project was estimated at Tk 8,446 crore in 2015 and was later revised to Tk 9,880 crore as the price of the land rose three times, according to Harunur Rashid Chowdhury, the project director. China Communication and Construction Company is constructing the tunnel. The Chinese government is funding the project and Bangladesh is bearing the cost of land acquisition and utilities.

The construction of the project began on December 5, 2017 and is due to be completed by December 2022.

Indian Railways completes longest electrified tunnel

The engineers of Indian Railways has added another feather in its cap by commissioning the longest electrified tunnel in India.

The total length of the tunnel is 6.6km and is situated between Cherlopalli and Rapuru stations which fall under the South Central Railways zone of Indian Railways. The newly constructed tunnel will help in providing viable rail connectivity between Krishnapatnam Port and its hinterland for goods train services. The newly constructed tunnel will help in reducing the travel time by 5 hours. At present, the average travel time taken by goods train from Krishnapatnam Port to Obulavaripalli is 10 hrs.

The construction of this tunnel

paved the way to operate freight trains in Obulavaripalli - Venkatachalam - Krishnapatnam Port new railway line for a distance of 113km. The section is now notified for commercial freight operations as well. This new line facilitates direct & viable connectivity between South Coast and West Coast.

Salient Features of Tunnel:

- Located between Cherlopalli to Rapuru stations and constructed in shape of 'Horse Shoe'.
- NATM is used and the cost incurred is Rs.460 crores
- Length of the tunnel is 6, 660 mts and is in straight alignment.
- The height of tunnel is 6.5m and the minimum height of contact wire is maintained at 5.2m.
- Full length lining is provided with 300mm thickness

Mistrikhola hydropower project

The construction of a 2,270m long tunnel of the Mistrikhola Hydroelectricity Project has been completed. The project is located at Narchyang of Annapurna rural municipality-4 in Myagdi district. The 42-MW-capacity project is being constructed by Robust Energy Pvt Ltd.

A 23m high dam has been constructed on the confluence of the Nilgiri and Ghalemdikhola streams. Similarly, the project has constructed a six kilometers road from Narchyangbesi up to the dam site. It has also constructed three Bailey bridges.

Works on construction of the tunnel had started on June 13, 2016. The tunnel is 926m from the dam site and 1,344.5m from the powerhouse outlet. 80 per cent of the construction of the dam and the powerhouse and installation of penstock pipe of the project has been completed.

The project is estimated to cost Rs 5.64 billion and it is being built through domestic investment. It is stated that the project was delayed nine years as the Nepal Electricity Authority (NEA) lingered in the construction of the 220-KV Kaligandaki electricity transmission line and the Dana sub-station.

Mistrikhola project is the largest of such projects constructed so far or which are under construction in Myagdi district.

Landslide traps 17 on Nepal site

It was an anxious night in June for 17 workers building the 111MW Rasuwagadhi Hydropower Project in Nepal after a landslide suddenly sealed the entrance to the 4km headrace tunnel they were working in.

Eleven Nepalese and six Chinese labourers had to wait 11 hours while a rescue crew of 38 people assembled from the Nepalese army and police dug at the rubble from the other side. They emerged into daylight on the morning of Friday, 21 June. Chinese contractor, China International Water and Electric Corporation, is carrying out civil work on the project for the Rasuwagadhi Hydropower Company. It is expected to begin generating by February 2020.

Zojila tunnel project up for bid again

The Indian government has invited fresh bids for the Zojila tunnel project in Jammu & Kashmir, after the construction contract was cancelled for the second time in three years. The tunnel, to be built at an altitude of 4,000 metres, will provide year-long connectivity between Srinagar and Leh as the current national highway that connects these two places remains shut for close to six months due to snowfall. But nine months after Prime Minister Narendra Modi inaugurated the work in May last year, the order given to Infrastructure Leasing & Financial Services, which is facing a cash crunch, has been cancelled.

The Zojila tunnel project was first announced during the UPA-II government. After four attempts to bid out under the private-public-partnership model and receiving dismal repose from the private sector since 2013, the government offered the project on an engineering, construction and procurement basis.

Penang to begin after seven-year delay

An unusually financed scheme to build a tolled undersea tunnel and three highways to improve traffic at Penang Island, Malaysia, is set to begin this summer, now that the concessionaire has raised cash through a land sale.

The concessionaire of the roughly $1.5bn scheme, Consortium Zenith Construction (CZC), was picked by Penang state government to deliver it in 2012, but the method of financing the scheme meant it had to sell some land first before it could start.

That is because the deal between CZC and Penang state sees CZC being paid with toll tunnel revenues and around 110 acres of reclaimed land, which CZC could sell to raise capital.

Seven years on, it has sold a 23-acre parcel to Boon Siew, a well-known Malaysian private company set up by late Penang tycoon, Tan Sri Loh Boon Siew, for around $204m, and so work started in August.

The first phase will be a 5.7km highway. The second phase is a 10.5km highway. Phase three is a 4km bypass, due to begin in August 2021.

The main element in the infrastructure programme is an undersea toll tunnel between Butterworth on the mainland and Gurney Drive on Penang island. This project will be carried out by China Railway Construction and is due to begin in 2023.

Bouygues sign in HK

Bouygues has inked a Hong Kong tunnel deal with the Highways Department (HyD) involving the construction of a 2.8km dual three-lane central tunnel on the Central Kowloon Route (CKR) project. Other aspects of the work include the construction of short stretches of cut-and-cover tunnels, a ventilation shaft, an adit and foundations for a ventilation building in Ho Man Tin. The forecast total of the costs is about HK$6.226bn.

The CKR will be a 4.7km dual three-lane strategic trunk road in Central Kowloon linking the Yau Ma Tei Interchange in West Kowloon with the road network of the Kai Tak Development and Kowloon Bay in East Kowloon. The CKR, anticipated to be commissioned in 2025, will relieve traffic congestion in the Central Kowloon road network. A total of six works contracts have been awarded under the CKR project, with a total value of about HK$23.2bn.

Pingshan-Yantian tunnel work completed

Work on the Mt. Maluan Tunnel for Pingyan Passage, which links Yantian and Pingshan, has been completed. The 7.9km tunnel has two independent entrances for southbound and northbound vehicles.

In addition, 80 percent of the road and bridge projects for the passage in the Pingshan section have been completed, but work on the bridge project on the Yantian side has been delayed due to a relocation dispute with Customs Training Base.

According to statistics from Shenzhen's transport commission, 80 percent of the work on the tunnel has been completed, while 65 percent of the bridge project to the south of the tunnel and 83.5 percent of the bridge project to the north of the tunnel has been completed.

Bantian-Yinhu Passage, which links Bantian in Longgang with Futian and Luohu districts, will cut the drive between Bantian and Futian CBD to 12 minutes.

The 10.7km Bantian-Yinhu Passage includes a 4.6km tunnel through Jigong Mountain in the Yinhu area. It starts at Shangbu Flyover on Nigang Road in Luohu District and ends at Banxuegang Boulevard in Bantian.

The tunnel and bridge projects account for 90 percent of the total road projects for the passage. The north-south road is expected to relieve traffic pressure at the former Meilin and Qingping checkpoints, and public transport will be given priority in the passage, with two 24-hour bus lanes and two peak-hour bus and HOV lanes on the six-lane road.

Macau underwater tunnel

The environmental impact assessment report for the planned underwater tunnel construction between Macau's New Urban Areas Zone A and B claims that the construction work is viable and will not impact the environment in the area. However, the construction was believed to maybe raise the risk of flooding in the city during typhoon season, while not impacting navigation around the Outer Harbour.

The report by the Land, Public Works and Transport Bureau (DSSOPT) stated that the authority will be responsible for taking appropriate measures in the field of environmental protection and pollution prevention in order to mitigate negative environmental impact during the work's construction. The government also promised to strictly implement various strategies and measures to control environmental impacts within an acceptable range.

The underwater tunnel will connect the New Areas Zone A and B landfills and will be approximately 1,300m long. It will also pass through the underwater area the Amizade Bridge and the navigation channel of the Outer Harbour. With four-lane dual carriageways with a speed limit of 60km per hour, the tunnel will also connect the artificial island of Hong Kong-Zhuhai-Macau Bridge, as well as providing an area to link the fourth Macau-Taipa Bridge.

Hiroshima Expressway Line 5 project

Robbins mega-sized slurry machine, measuring 13.7m (44.8 ft) in diameter, has made its first cut into hard rock. The epic launch at an urban jobsite was made possible by Onsite First Time Assembly (OFTA) of the TBM in Japan for the Hiroshima Expressway Line 5 project. The contractor, a joint venture of Obayashi-Taisei-Kosei, had a strict timeline of eight months to adhere to when it came to machine assembly. "This deadline was very important. After assembling the TBM, I think OFTA was appropriate for this project," said Mr. Ryota Akai, Deputy Project Manager for the Obayashi JV.

Due to the project location there were also restrictions on delivering the TBM—in order to meet controlled transportation limits within the city, the TBM had to be divided into small transportable weights and sizes, then assembled in a small jobsite measuring just 30m (100 ft) wide x 60m (200 ft) long. The 2,400 metric ton (2,650 US ton) machine will bore 1.4 km (0.9 mi) of the 1.8km (1.1 mi) long tunnel that, once completed, will significantly improve traffic conditions in Hiroshima.

The massive machine is the country's first foreign-made large diameter Slurry TBM to excavate hard rock in Japan. "There is a lot of hard rock in Hiroshima," said Mr. Akai, "and Robbins has a lot of experience boring hard rock."

The machine is expected to encounter granite with rock strengths up to 130MPa (19,000 psi) UCS. Those involved in the project are excited to see what effect this will have on how Slurry TBMs are used in the future. "The development of this TBM is a milestone," said Mr. Kiyomi Sasaki, General Manager of Robbins Japan, "it will lead to new tunnel applications worldwide."

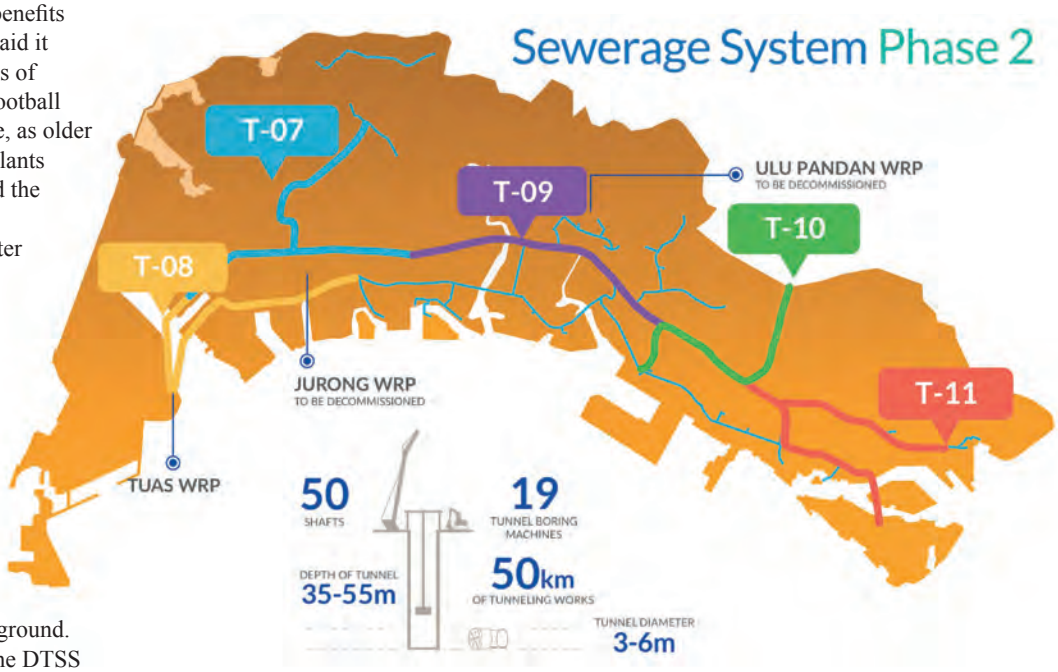
The design of the Slurry machine is robust in anticipation of potentially abrasive rock conditions and water pressures up to 13 bars. "The Robbins machine is very tough, for example the weight is very heavy. The cutterhead, both its material and structure, are very tough. It will not break in hard rock," said Mr. Akai.

In preparation for the conditions, the machine was designed for 20-bar water pressure. The robust cutterhead was fitted with 20-inch and 17-inch diameter pressure compensating cutters, which utilize a patented design to effectively operate under high pressure. The joint venture intends to change the disc cutters an estimated 10 times during the bore as part of the machine's maintenance.

The new Expressway Line 5 tunnel will directly connect Hiroshima's urban area with a major national highway network and is expected to improve access to Hiroshima Airport. Tunnel completion is planned for 2020.

Singapore DTSS II

Tunnelling work has begun on a massive underground sewage superhighway in western Singapore – the most ambitious project of its kind here to date. On track to be completed in 2025, the underground labyrinth of pipes will comprise 40km of deep tunnels and 60km of link sewers, traversing 100km across the western half of Singapore, including the downtown area and some new developments in the Jurong Lake District, Tengah Town and the Greater Southern Waterfront. Waste water will be conveyed via gravity to centralised water reclamation plants for treatment and recycling into Newater.



Highlighting the economic benefits of DTSS phase 2, the PUB said it will allow allow 150 hectares of land, about the size of 214 football pitches, to be made available, as older existing water reclamation plants and pumping stations around the island are phased out. These include the conventional water reclamation plants at Ulu Pandan and Jurong and the intermediate pumping stations.

Work officially began on Thursday (April 4) at a PUB site in Jalan Bahar with the launch of the first tunnel boring machine, which will burrow through the ground to create tunnels 3.5m in diameter below the ground.

It is the second phase of the DTSS (Deep Tunnel Sewerage System) project, where the PUB, Singapore's national water agency, will break new ground in a bid to make Singapore's water systems more sustainable. The first DTSS was completed in 2008, to serve eastern Singapore. Tunnelling work on phase two of the DTSS is targeted to be completed by 2024, after which used water from homes, offices, and industries will be conveyed via two tunnels – the 30-km long South Tunnel, which is for domestic use, and the 10km Industrial Tunnel, for industrial use.

Phase two of the DTSS project will cost $6.5 billion in total, with $2.3 billion devoted to a total of 19 tunnel boring machines that will be deployed to dig deep underground to create a complex network of tunnels and link sewers.

This phase of the DTSS will also be the first time that smart tunnel monitoring systems and fibre optic sensors will be used to detect problems before they pose risks. For instance, a smart tunnel monitoring system known as the Shaft and Tunnel Excavation System (STEMS) will act as a nerve centre, providing real-time updates on the location of the tunnel boring machines, making sure that operations throughout the construction period remain safe and go smoothly, with minimal disruption to urban structures above. There will also be a fibre optic system in place to monitor the structural integrity of tunnel linings. Additionally, isolation gates will be put in place to allow parts of the tunnel to be sectioned off for repair work.

The DTSS phase two will also be the first project in Singapore to use ventilation equipment called air jumpers, which manage air flow in the tunnel, by push odorous air further downstream to be treated at an odour control facility.

Singapore North-South Corridor (NSC)

The Land Transport Authority (LTA) has awarded a contract to construct a 800m long dual 3-lane road tunnel, an MRT station box and commuter facilities between Sin Ming Avenue and Ang Mo Kio Avenue 3 to Shanghai Tunnel Engineering Co. (Singapore) Pte Ltd. at a contract sum of EUR400.84 million (SDG615.90 million). The tunnel is part of the 21.5km NSC (North-South Corridor) N109A Project in Singapore. The NSC is Singapore's first integrated transport corridor that will connect ECP in the south to Admiralty Road West in the north. It's expected to be completed in 2026.

Woodlawn zinc-copper mine

Preparation for the first processing campaign of high-grade underground ore is well advanced and will proceed following the current ramp-up program. Underground mining continues to perform well, with production in the last three months exceeding plans, and development ore from the G2 Lens stockpiled at the crushing circuit in readiness for processing.

Based on the current Ore Reserves mine plan, the project is expected to produce three concentrates at an average annual gross production rate at steady-state of 40,000t zinc,10,000t copper, 12,000t lead, 900,000 ounces silver and 4,000 ounces gold over an initial mine

life of 9.3years. Significant potential for mine life extensions exists through the conversion of high grade underground resources and further exploration success.

The Woodlawn Mine, was closed in 1998 when its operating company went into receivership. Canadian-Australian mining company, TriAusMin, was granted approval from the NSW State Government to proceed with its re-opening in July 2013. The Woodlawn Mine that is located about 200 kilometres from Sydney produced 13.8 million tonnes of ore from 1978 to 1998. The ore averaged grades of; 0.5 grams per tonne of gold, 74 grams a tonne of silver, 1.6 percent copper, 3.6 percent lead and 9.1 percent zinc.

Victorian gold rush revival

It is believed 80 million ounces of gold still remains underground in regional Victoria. When fortune seekers from across the globe flocked to central Victoria's goldfields in the 1800s they worked with limited equipment — meaning much of the gold remained out of reach. Now the state is experiencing a gold rush revival of sorts, with production doubling in the past five years.

Fosterville mine in Bendigo in central Victoria has begun producing a reserve of 2.7 million ounces of high quality gold, and many other mines around the state are also ramping-up production.

Miners have discovered there is still plenty of gold remaining deep underground. Ian Holland, vice-president of the Australian operations of Fosterville's parent company, Kirkland Lake Gold, said things ramped up about three years ago, when the company invested in deep drilling. "The ore body really started to increase in grade at a depth of about 800 metres-plus below the surface," he said. The mine is expected to produce between 570,000 and 610,000 ounces of gold each year for the next three years.

"As of the last couple of quarters, Fosterville has been in the top five gold mines in Australia by volume, and given the grades we are seeing, we are the lowest cost, highest margin pure gold producer in the country," Mr Holland said.

The mine produced 31 grade gold, which equated to 31 parts of gold per million. "The average underground mine might produce gold in the order of four to six grams, and the average open pit mine might be in the order of 1 to 2 grams," Mr Holland said. "So these are exceptional grades." As a result of the discovery, the mine has been able to double its workforce to 600 workers.

Across the state, gold production has doubled in the past five years as dormant mines are revived. Peter McCarthy, a former mining engineer, now the chairman emeritus of ACM Consulting, helped re-establish the Castlemaine Goldfields mine in Ballarat after a century-long hiatus. "Victoria was the greatest gold producer in Australia until we were eclipsed by Western Australia in about 1980," Mr McCarthy said. "And we're really starting to see things pick up again."

Other Victorian mines prospering are Costerfield Mine, near Bendigo, and Stawell Mine, in north-west Victoria, which restarted operations last year.

Much of the gold in Victoria is deep underground, which means a high initial investment for companies. But the high price of gold, which exceeded $2,000 per ounce for the first time on record last week, was helping make that investment more worthwhile.

It is believed most of the remaining gold in Victoria was in three key spots: beneath existing old mines, beneath the Murray Basin sediments north of Bendigo, and beneath the basalt plains in Western Victoria.

Ballarat miner warns on gold royalty

A new gold royalty confirmed in the Victorian government's state budget and Stephen Jeffers, boss of the Ballarat gold mine says,"I don't know how we're going to survive."

The mine underneath the city of Ballarat currently employs about 160 direct employees and a further 70-80 contractors full-time, but the announcement of the 2.75 per cent gold royalty has placed an unexpected cloud over the mine in the famous Victorian goldfields city.

Victoria is currently the only Australian jurisdiction without a gold royalty and the royalty will apply from January 1 next year.

The underground Ballarat gold mine was opened in 2005 in the heart of the goldfields made famous by the Victorian goldrush of the 1800s. Gold from the mine was used to make the gold medals used in the Melbourne Commonwealth Games of 2006.

Victoria will borrow big to build the Andrews government's big ticket infrastructure projects, with the state's debt set to hit $55 billion within four years.

The Minerals Council of Australia also criticised the gold tax, with the group's chief executive Tania Constable saying she was shocked by the state government move. "We're disappointed and extremely surprised that the Labor government here in Victoria has taken the position that they have. Particularly because they didn't talk to us," she said.

Energy store in a defunct zinc mine

An energy storage startup called Hydrostor is planning to build an Advanced Compressed Air Energy Storage (A-CAES) project in Australia, using an out-of-operation underground zinc mine as a container for the compressed air.

Hydrostor announced its plans this week after being awarded AUD $9 million (USD $6.4 million) in grants from Australian government institutions.

Compressed air energy storage (CAES) is a sort of physical battery (as opposed to a chemical battery) that uses excess electricity to compress air. The compressed air is stored in a tank, in a balloon, or in an underground cavern. When more electricity is needed, the compressed air is heated, which drives a turbine as it expands.

Ideally, this allows more renewable energy to be added to a grid: for example, if there's a lot of wind at night, when not many people are using electricity, that excess electricity can be used to run the compressor on a CAES system. The stored energy can then be used 12 hours later when the wind dies down.

Traditional CAES usually can't be carbon-neutral because it uses natural gas to heat up that compressed air. However, this setup uses significantly less natural gas than simply adding another gas turbine to the grid, so traditional CAES is seen as a way to reduce carbon emissions on the grid.

Hydrostor's A-CAES system, notably, is able to retain the heat that's removed from the ambient air as it's being compressed. The so-called adiabatic system stores that heat separately from the compressed air, and when it's time to put electricity back on the grid, the compressed air is warmed up using that stored heat.

The project is relatively small, with a power rating of just five megawatts (MW) and a discharge duration of two hours (for 10 megawatt-hours). But A-CAES systems are extremely rare, and this project, which is projected to be complete in 2020, could pave the way for larger such projects.

This particular project will be built at the Angas Zinc Mine, outside of Adelaide in South Australia. The facility will compress air and inject it into the mine, using a column of water to hold the air in place. "During charging, compressed air displaces water out of the cavern up a water column to a surface reservoir," a press release from Hydrostor states. "During discharge, water flows back into the cavern forcing air to the surface under pressure where it is re-heated using the stored heat and then expanded through a turbine to generate electricity on demand."

DIESEL FUMES: a major concern

Exposure to high levels of diesel fumes could well be the next biggest occupational health threat since asbestos, exposing the Australian and world mining and trucking industries to multiple public liability claims says hydraulic engineer and inventor, Norm Mathers.

Despite numerous medical studies over the past decade finding that long term exposure to diesel fumes is likely linked to an array of serious health issues, particularly cancer and dementia, large multinational trucking and mining companies have continued to ignore the warnings.

As a result of these warnings, the European Union Commission has demanded direct action on reducing use in trucks and buses by 2025. Further, in June 2012 the International Agency for Cancer Research (IARC) classified diesel emissions (including diesel particulates matter) as a known human carcinogen.

Similar to coal dust, diesel exhaust includes inorganic particulate matter, which is largely carbon. Being inorganic, it is likely to be insoluble in the body, and, it would seem, could affect the body in a similar manner as coal dust which has been found to be a direct cause of black lung disease.

Mr Mathers conceded that companies have introduced chemical exhaust cleaning and improved engine efficiencies, however they had made no concentrated effort to meet the EU commission initial 30 percent CO2 reduction targets.

Mr Mathers has investigated the issue with worlds' leading scientists and engineers through his Australian innovation company, Mathers Hydraulics Technology (MHT), which has developed a technology which reduces diesel emissions by turning engines off when idle and thereby reducing emissions significantly. Stop/Start technology on petrol cars has proved to be both highly effective and widely accepted in reducing emissions. However, up until now the same benefits of stop/start technology have not been available for larger diesel engines because of the need for a high speed starter motor.

Using its fuel saving vane pump, MHT has developed a high speed stop/start motor which also powers an accumulator during braking for energy storage. This currently wasted braking energy is added back in to reduce fuel use.

In 2011, MHT in collaboration with engineers from Mack Trucks and Volvo in Brisbane outfitted two tip/dump trucks with the MHT emissions reducing technology.

A serious threat exists for mines that use diesel machinery underground, exposing workers to high levels of nano diesel particulates. Nano diesel particulate matter (nDPM) is so small it is described as being less than a hundredth of the width of a human hair. The tiny particles, when inhaled, can reach deep into the body and stay there for months.

Recent media reports have cited a recent study in Western Australia which highlighted the high risk of lung cancer among miners in confined spaces underground.Testing at a Western Australian mine found levels of up to a million nano diesel particulates per cubic centimetre.

Despite numerous medical studies over the past decade finding that long term exposure to diesel fumes is likely linked to an array of serious health issues, particularly cancer and dementia, large multinational trucking and mining companies have continued to ignore the warnings.

DeGrussa mine

Sandfire Resources has strengthened the mine plan of the DeGrussa copper-gold project in Western Australia, carrying its mine life to mid-2022. The company has updated the ore reserve and mineral resource for DeGrussa, including the Conductor 1, Conductor 4 and Conductor 5 deposits, as well as the Monty mine. DeGrussa has received a net increase in underground ore reserves of 0.4 million tonnes and 2000 tonnes of contained copper, after accounting for yearly mining depletion of around 1.6 million tonnes.

"This is a positive outcome which reflects our continued success in replacing ore reserves and identifying extensions of some of the key volcanogenic massive sulphide (VMS) lenses at DeGrussa," Sandfire managing director Karl Simich said. "

The operation initially had a mine life of seven years, which would have seen the end of the site in mid-2019.

Charters Towers

The underground mining operations at the company's Charters Towers (including Central and Imperial mining areas) remained on maintenance during the March quarter, with no gold production. Meanwhile, the Citigold is planning to employ contractors to operate

plant, equipment and undertake exploration drilling; the number of contractors is expected to increase as the project grows in scale.

Citigold has already invested over $ 200 million in acquiring the gold deposits, developing the mines and infrastructure at Charters Towers; Test mining operations have produced 100K ounces of gold.

Going forward, the company is targeting to be a 300,000 plus ounces per annum ultralow-cost gold producer in five years using state of the art technologies and efficiencies, which in turn is expected to generate substantial profits to shareholders in harmony with the local environment.

The resumption of mining is contingent on a sufficient level of capital financing, with active planning and scheduling ongoing. The Central mine will be the first to reopen. The company is prioritising geological data, technical evaluation, project assessment, feasibility and design to prepare for the upcoming period of expanded infield Charters Towers area exploration works and mine planning. In addition, Citigold's initiatives are further assisted by the relatively benign chemical properties of the local rocks and the operational care taken at the sites.

Citigold's innovation program is driven by extensive R&D while it is also considering to further modify previously trialled technologies for wider application. The recent strength in the USD gold price hovering over $ 1,250 per ounce, has further reaffirmed the significance and enhanced the appeal of the production ready gold project.

Citigold is inherently cautious and strives for favourable achievements on the health, safety, community and environment front. The company aspires to become a net zero emissions underground mine and envisages a period when renewable energy will eventually become the primary energy source. The Lost Time and Disabling Injury Frequency Rate (LTIFR and DIRF) remains at zero.

Opening of historic Lapstone Hill tunnel mooted

Blue Mountains City Council is urging the New South Wales state government to open the Lapstone Hill Tunnel. The Minister for Water, Property and Housing Melinda Pavey has been asked to support the project by persuading the government to invest in the rehabilitation and restoration of the tunnel so that it can be readied for opening to the public, in accordance with the Eastern Scenic Escarpment Master Plan.

"The Lapstone Hill Tunnel is a significant historic structure within the Eastern Scenic Escarpment, with great potential for adaptive re-use. In particular, re-activation for public use that supports the amenity, economy and liveability of the lower mountains," Blue Mountains Mayor Mark Greenhill said. "The Eastern Scenic Escarpment Master Plan recognises the value of the site in that regard and contemplates activation for public use, subject to contamination and stabilization issues being resolved by the current owner, the NSW Government. Addressing these issues is necessary before the site can be considered for activation and/or transferred into a more active management regime by an appropriate land manager," Greenhill said. Ward 4 Councillor Brendan Christie, who is working with the mayor and community groups to advocate for the opening, said the tunnel was the missing link in activating the area for residents and visitors. "Opening Lapstone Hill Tunnel would connect Glenbrook and Lapstone villages with Leonay and Emu Plains, as well as Penrith's Great River Walk. It would provide the community with safe access across the area," he said. "Opening the tunnel is the missing link, in regards to activating the area. The potential is huge in regards to allowing the community to appreciate the tunnel for its history, as well as improving access.

By working together we may also be able to boost tourism and our local economy, by providing a unique location for visitors looking for adventure-style activities," the councillor said.

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Garden Island - the tunnels complex under the hill

Presentation to Australian Tunnelling Society 19th June 2019

By Colin Randall - Naval Historical Society of Australia

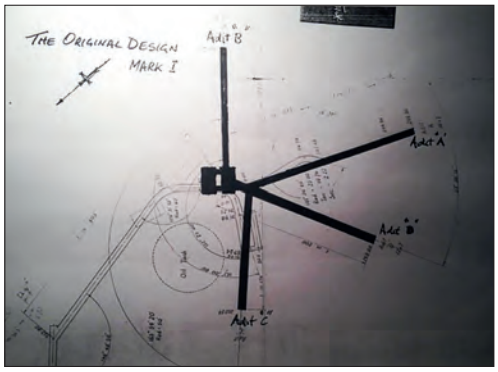
On 13th February 1941 there was a most secret decision by the Australian Government to construct ARP tunnels on Garden Island. The potential for an attack by the Japanese on Garden Island with 70 tons of bombs dropped in 24 hour period underscored the need for air raid protection for valuable dockyard personnel.

'Billy' Hughes was the Minister for the Navy from 28 October 1940 to 7 October 1941.

On 7th December 1941 the Japanese attacked Pearl Harbour and on 11th December 1941 Excavation commenced on the ARP tunnels under the hills on Garden Island to accommodate 1400 persons.

The works were undertaken by the Metropolitan Water Sewerage and Drainage Board (MWS&DB) who had been working at Potts Point as part of the Captain Cook Graving Dock Project.

The Financial Certificate dated 30 December 1941 'Provide system of tunnelling under the Hill" was approved at an estimated cost £15,150.



The original design was for four tunnels fanning out from a central hub.

The tunnels were to be supported with heavy timber sets following standard MWS&DB tunnelling procedures – namely:

- Approximately 4 feet of tunnel is made every shift and two shifts per day are worked, thus the tunnel progresses at 8 feet per day.
- The working face of the tunnel is drilled, the charges fixed and exploded. After a safety lapse, the men re-enter the tunnel, followed by the loco propelling a side tip hopper wagon.
- At the working face, the hopper wagon is filled by hand and by a rail mounted mechanical belt loader from where the loco hauls the spoil to the tip point.

On 12th January 1942 it was decided to excavate a fifth tunnel to provide access to the Western Ferry Wharf and to enable the ARP complex to accommodate 2500 people.

The expected total workforce for five tunnels - based on 2 shifts per day and 6 days per week with initially hand pushed wagons:

- Engineer - 1
- Shift In- charge foreman – 2
- Shotfirer – 2
- Leading hand - 1 per face – 10
- Face crews – 4 experienced tunnellers per face – 20
- **Total – 35**

The tunnels were all named :

- **Adit A – Petticoat Lane -** had a cut and cover entry, then a 1 in 10 slope, followed by a 1 in 12 and final connection at 1 in 229
- **Adit B – Gun Wharf Tunnel –** was horizontal (but actually 1 in 102.5)
- **Adit C – Lambeth Walk –** was horizontal (but actually 1 in 174)
- **Adit D – Saunders Corner –** was horizontal (but actually 1 in 200)
- **Adit E – North West Passage –** was horizontal (but actually 1 in 505)

It is considered that a slope of 1 in 200 was required for natural drainage.

On 15th February 1942 was the surrender of Singapore and on 19th February 1942 Darwin was bombed. The Japanese dropped more bombs on Darwin on 19 February 1942 than at Pearl Harbour. The carrier based aircraft including Aichi D3A Vals and Nakajima B5N Kates dropped 82,550 kilograms of bombs in the first raid, whilst the Zero fighters intercepted American fighters and straffed installations. Mitsubishi G4M Bettys and G3M Nells dropped a further 32,050 kilograms of bombs in the noon raid on the RAAF Station.

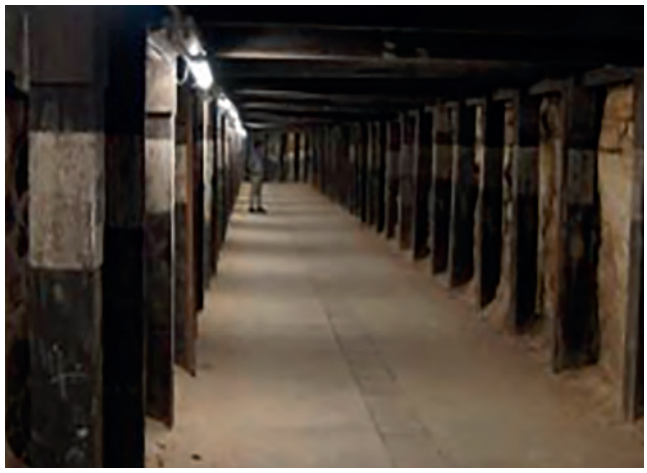
The total number of bombs dropped was two-and-a-half times that dropped at Pearl Harbour, and 83 per cent of the tonnage unloaded at Pearl Harbour on 7 December 1941.

On 17th March 1942 the five tunnels on Garden Island were nearing completion but the tunnellers were taken away to undertake urgent construction of underground oil tanks in Darwin. So, three tunnels were stopped and only two pushed forward.

Locomotive continued to haul spoil out of Adit 'B with hand pushed wagons hauling from Adit 'C'. The likely workforce was:

- Engineer - 1
- Shift In- charge foreman – 2
- Shotfirers 1 per shift– 2
- Leading hand 1 per face – 2
- Face crews – 5 inexperienced CCC workers per face total 10
- Loco driver – 2
- Tip hands – 4 inexperienced CCC workers
- **Total - 23**

On 31st May 1942 the Japanese attacked Sydney with midget submarines and on 8th June 1942



Completed timber supports 1942. As installed in Dogleg Tunnel on Cockatoo Island by MWS&DB in September/October 1942

Sydney was shelled by Japanese Submarine I-27. Since the 1930's Garden Island's electrical supply was from the main Sydney County Council grid by underwater cable from Potts Point. The potential for damage to that supply from further aerial bombardment drove the decision to install a secure underground alternate emergency diesel generated electricity supply. The power on Garden Island was AC while power on ships of the day were DC. There were transformers installed in the tunnels, but the records do not show whether they were just AC step down transformers or mercury arc rectifiers to convert AC to DC at 110v for supply to ships alongside.

Following the installation of the 12 inch blast baffle walls in Adits A,B, C and D all excavated material would have exited by Adit E by way of the GEMCO battery loco drawing 22 cu. ft. side tipping wagon on the 2' ft gauge rail laid in the tunnels.

A further tunnel was excavated for fire-fighting foam pumps.

On 8th October 1942 the tunnel complex was completed. Problems that had occurred during the construction included inefficient labour, piece meal authorisation, and delivery of material onto Garden Island.

Total length of tunnels was 2000 feet. Total volume excavated was 7,900 cu.yd (includes tunnels, chambers and ventilation shaft). Other works included installation of diesel generating plant, electrical distribution and associated ventilation, installation of water, sewerage, pumping and drainage, and installation and removal of telephone exchange at a final cost of £67,036.

It would appear that the drawings prepared were prepared later in 1942 or early 1943 when the MWS&DB are justifying the higher cost. After completion of the complex, the probability is that they were never used except for possible ARP exercises.

Whether during the Korean War and/or Cold War there was ever an ARP exercise it is not known. The date of the removal of the emergency diesel generator and the Simplex Fire Fighting Foam is not known.

By the 1960's the tunnels had been abandoned and the timber sets for roof support had either rotted out or been eaten by termites. In the 1970's the tunnels were upgraded with the removal of the blast baffle walls, new steel sets for roof support and concreted were the soft sandstone walls had weathered. The fully lighted tunnels are used for storage and to provide distribution for diesel pipeline and power supplies.

Acknowledgements

- Sydney Water / WaterNSW Historical Research Archive for provision
  Sydney Harbour Trust for provision of photographs of Dogleg tunnel on Cockatoo Island of photographs
- Norm Rivett, Naval Historical Society Volunteer, for archival data collection
- David Stockman, Naval Historical Society Volunteer, for archival collection data

Design & Construction of **Pedestrian Access Tunnels below an Existing Operational Metro Tunnels & Station**

SENTHILNATH. G. T, M.Eng, M.Sc, CPEng, MIEAust, NER

Abstract:
A new underground station is added into Outram Park Station as a part of Thomson Line MRT/ metro in Singapore and this is built next to two operating metro lines. Once the underground station is completed, it is required to connect this infrastructure with the platforms of existing metro lines for the passengers to interchange between the metro lines. This paper presents design and construction issues of two such pedestrian linkway access tunnels built for this purpose. Two tunnels with cross-sectional area ranging from 50m2 to 85m2 are excavated below an existing operational rail tunnel (with vertical clearance of less than 2.7m) and below an operational metro station. The tunnel excavation below the operational metro tunnel is carried out using pipe roof method and the tunnel excavation below the existing station base slab is carried out by underpinning the structure as the excavation progressed. This paper gives an insight into the design considerations, construction methodology and summarizes the learnings based on instrumentation and monitoring results.

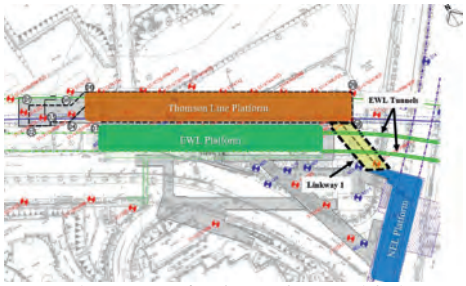
Keywords: Pedestrian Linkway, Pipe jacking, excavation methods, underpinning

1. Introduction

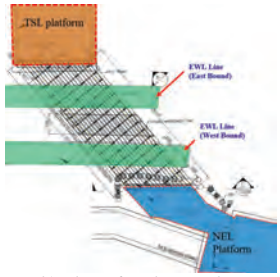
With the construction of new underground public transport systems, there is a need to construct Linkway tunnels to integrate them with the existing transport network and to link them with accessible entrance and exit locations. Often, the preferred construction method for such Linkway tunnels are cut and cover constructions with temporary excavation retaining walls and strutting. However, in a densely populated area, this would require multi-staged traffic diversions and advance utility diversions. In some cases, the Linkway tunnels can also be below existing buildings making it impossible to carry out cut and cover construction method.

The pedestrian Linkway tunnels discussed in this paper are part of infrastructure connecting the new Outram Park Station in Thomson Line (TSL) to existing Outram Park stations in East-West Line (EWL) and North-East Line (NEL) metro routes. Linkway 1 is constructed underneath the existing live tunnels to provide access from NEL to TSL station structure. Linkway 2 is constructed underneath the existing station with linking access directly to the platform of EWL by escalators and staircase. Figure 1 and Figure 2 show schematic locations of Linkway 1 and Linkway 2 respectively.

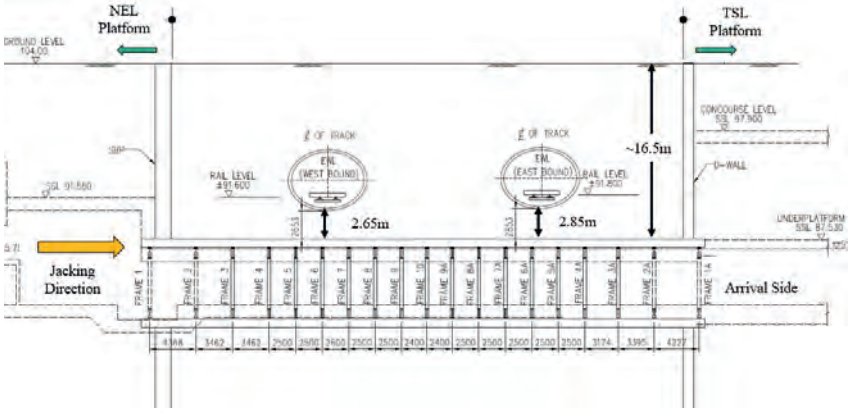
Linkway 1 tunnel has to accommodate pedestrian Linkway of dimension 13.1m wide and 6.5m deep and this tunnel is constructed below operational EWL



a) Overview of Linkway 1 location (plan)



b) Plan of Linkway 1 location



c) Longitudinal section of Linkway 1 and EWL tunnels undercrossing

Fig 1. Schematic location of Linkway 1

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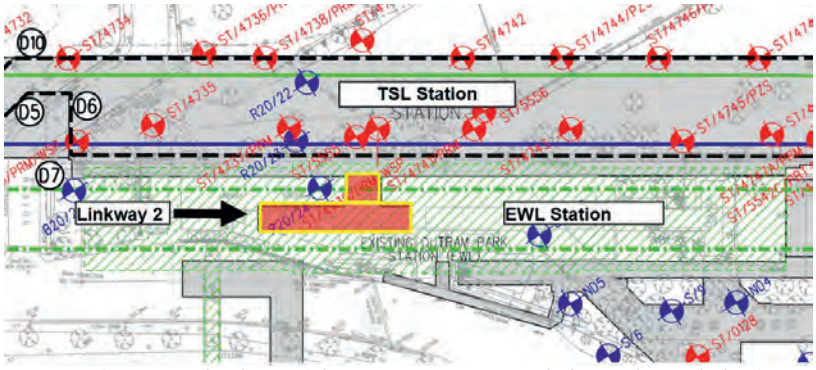
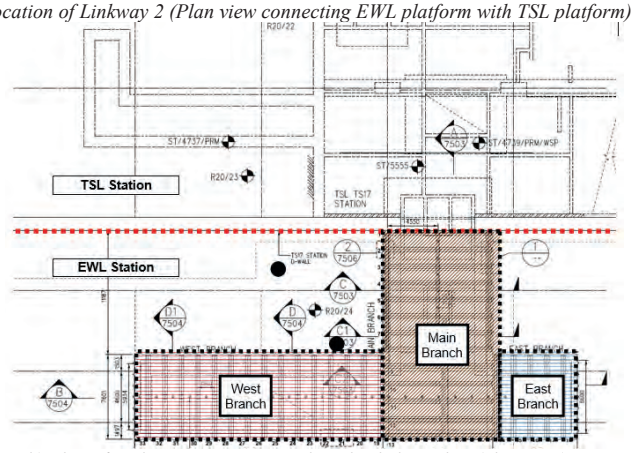
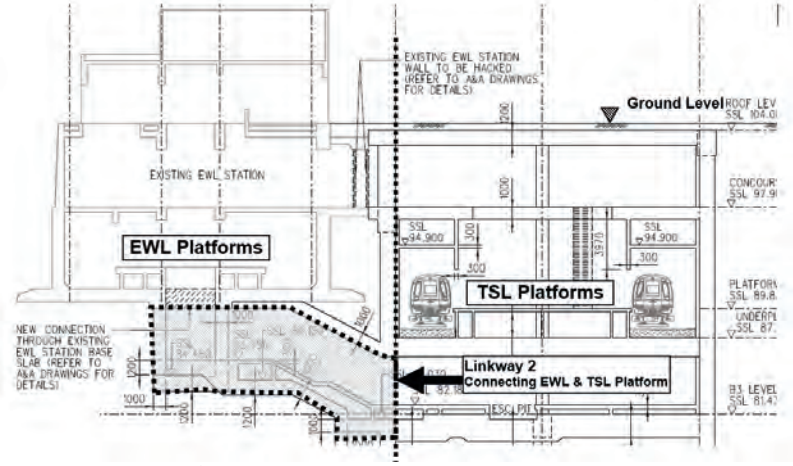


a) Location of Linkway 2 (Plan view connecting EWL platform with TSL platform)



b) Plan of Linkway 2: Main Branch and side branches (plan view)



c) *Longitudinal section of Linkway 2 (along main branch)*

Fig 2. Schematic location of Linkway 2

tunnels at around 45 degree angle with a minimum vertical clearance of 2.65m. The existing tunnels have an internal clear diameter of 5.3m, built with precast concrete segmental rings of 1.0m width and 225mm thickness. The rings are arranged in 5+1 key configuration with a C40 design concrete grade. The EWL tunnels (EB = East Bound, WB = West Bound) are almost at same level as the tunnels are close to the station. The rail levels are ~91.6mRL, which is approximately 1.548m below their respective tunnel axis.

Linkway 2 excavation is carried out below the existing EWL station to create an underground link between TSL platforms and EWL platforms. Due to high volume of passengers anticipated at this interchange, the passenger Linkway will be of 9.3m wide and 6.2m deep. The existing station is seated on a raft foundation which is mostly highly weathered rock of siltstone and mudstone (known locally as Jurong Formation with weathering grade ranging from SIV to SVI). Linkway 2 excavation will begin from TSL platform and progress towards the centre of EWL platform. Along the centre of EWL station slab, two side drift (east branch and left branch) tunnels are excavated to accommodate the staircase and escalator parallel to the platform. The central portion of the base slab with opening in the slab, is a thickened strip that extends the full length of the EWL station. This strip is 1.5m thick and includes two hidden reinforced concrete beams located within its depth. These beams in the raft were designed in 1990's to act as ground bearing strip footings to the internal station columns sitting exactly above this EWL central station slab.

2. Geology and Ground Condition

Both the proposed Linkway tunnels will be excavated in Jurong formation. Nearest boreholes indicate that the tunnel excavation will encounter weathering grade SV and SIV. Few boreholes suggest slightly sandy / gravelly silt at the crown. During the soil investigation it was noted that weathered layers of sandstone in combination with water pressure could lead to instability of excavation. Within the first 3-4m from ground, there is a thin layer of fill material underlain by fluvial deposit and occasional pockets of organic clay. Below this is a completely weathered zone of Jurong formation. The properties improve generally with depth. The Jurong formation is of late Triassic to early Jurassic age and comprises interbedded sandstones, siltstones and mudstones that in location, dip steeply. The rock mass is dominated by the fractures and depending upon the condition of the fractures varied flow of water ingress are experienced. Under wet condition, the rock mass is found to deteriorate rapidly. Rock strength was variable ranging generally from 0.5 MPa to 5 MPa. For design purposes, Table 1 parameters were used.

Field permeability test indicated permeability in the range of $1x10^{-7}$ m/sec for the weathered Jurong Formation.

Table 1: Design Parameters

	Jurong Formation			
	SVI	SV	SIV	SIII
Unit weight [kN/m^3]	20	21	24	25
Effective angle of friction [degree]	31	33	33	36
Effective cohesion [kPa]	0	10	15	30
Undrained shear strength cu [kPa]	100	250	NA	NA
Young's Modulus E' [MPa]	33	208	250	400

3. Design Concept

3.1 Linkway 1

Tunnel displacement causes deformation of the ground between the tunnel and the subsurface infrastructure and hence results in subsidence at the underground infrastructure. In this case, the clearance between the Linkway tunnel and the existing EWL tunnels is less than 3m hence there is a high risk of EWL tunnel damage if there is any face collapse during Linkway 1 excavation. To address this concern, based on experience in Singapore (Badurdeen and Senthilnath 2017), it was proposed to install pipe-jacked steel pipes to form a reinforcement layer between the EWL tunnel and the Linkway 1 excavation tunnel. This formed a high stiffness boundary and provided an advance face support to enhance the stability of the tunnel prior to tunnel excavation. The steel pipes of 0.813m diameter was proposed to be jacked over the projected tunnel crown to form a layer of reinforced layer which prevents the flow of soil into the tunnel at the periphery and at the face when the Linkway 1 excavation is in progress. Subsequently, steel rib/ steel frame supports are installed inside the Linkway tunnel at 2.5m spacing as the tunnel excavation progressed. Typical roof reinforcement with pipes is shown in figure 3(a). Lim et al. (2000) observed

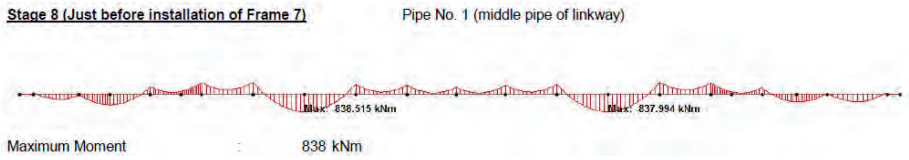


Fig 4. Typical bending moment distribution in the roof pipe

that around half of the settlement during the tunnel excavation in Jurong formation could be attributed to elastic compression during water drawdown. Hence in our design scheme, we proposed a water tight system with interlocking pipes (provided with T-clutch joints) – shown in Figure 2 (b) and (c) and ground water recharge wells were planned along the excavation length to recharge the ground water drawdown due to excavation as a contingency measure.

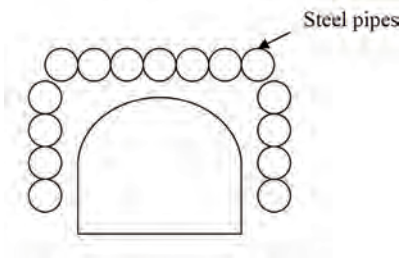
3.1.1 Installation of Pipe-Roof and tunnel excavation

Once all the interlocking pipes (52 nos) are jacked, first frame is installed within the shaft – (acting as a portal frame) and the excavation of tunnel was started within the box structure created by the interlocking pipes. The subsequent support frames are installed as the excavation progressed along the Linkway tunnel. The pipes at the roof level (pipe no. 1 to 18) act as a continuous beam supported at the frame locations. In intermediate stage of post-excavation (and just before the installation of frame), the roof level beams experience the maximum bending moment and deflection. The last installed frame experiences the maximum loading as the excavation proceeds. With the next frame installation, there was slight unloading of the previous frame. This was anticipated in the design and hence a staged excavation model was used to simulate the complete excavation cycle. Figure 4 presents typical bending moment distribution in the top pipe-roof in a given stage.

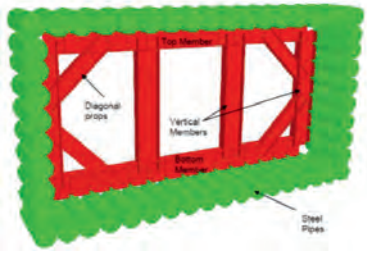
The usual approach of Rabchiwich / NATM is to utilize the strength of the soil. But to utilize the strength, we need to mobilize some movement in the ground. However, in our case, the allowable limits are very strict hence the member sizes are relatively heavy and also happen to take more loads as stiffer elements tend to attract forces.

3.1.2 Impact on existing tunnels during tunnel excavation

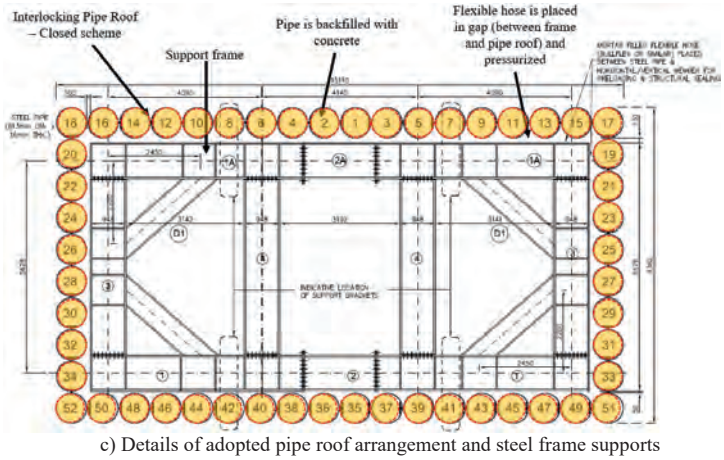
To assess the ground deformation due to Linkway 1 excavation, a 3D model numerical analysis was carried out. Since the analysis was on a 3D model, no ground relaxation was applied prior to any excavation step or activation of ground support elements. The model includes simulation of each excavation step and subsequent installation of steel frames. To arrive at reasonably conservative estimate of construction impact on existing tunnel, the ground support of the excavation face in Linkway 1 (such as glass fibre face dowels, sprayed concrete, etc) was not considered in the analysis model. The analysis was carried out with an assumption that the Linkway 1 excavation will be carried out from both sides of the tunnel however during the final stages, as the unexcavated soil between the either face of excavation is reduced, the construction sequence is simulated (and was proposed in design drawings) for excavation from one side. Figure 5 presents the numerical model and visualization of frame location / unexcavated soil during the final rounds of excavation.



a) Typical pipe roof reinforcement: Gate type arrangement (Tan et al 2003)



b) Pipe roof arrangement adopted in Linkway 1



c) Details of adopted pipe roof arrangement and steel frame supports

Fig 3. Proposed water-tight piperoof system

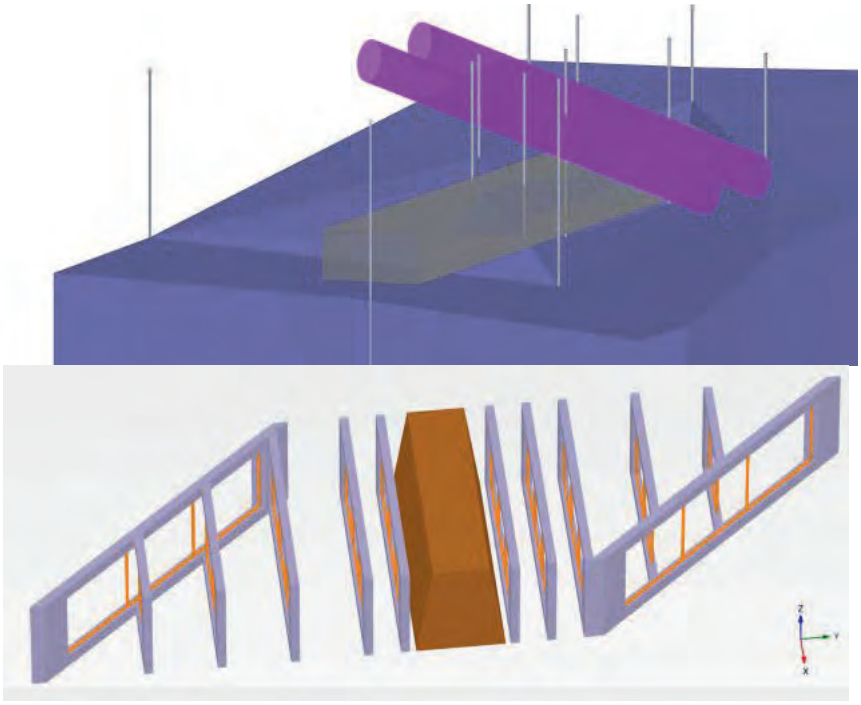


Fig 5. Numerical model and excavation sequence visualization

In addition to assessing the ground displacement due to Linkway 1 excavation, it was important to understand the behaviour of the tunnels and change in diameter of tunnel (if any) due to Linkway 1 excavation. Following structural limit states were studied in this project to ensure that the existing tunnel linings are within structural limits.

- Ovalisation: To check distortion involving increase in vertical diameter and decrease in horizontal diameter. This causes increase in bending moments in the concrete segments and causes rotation at the segment joints.
- Squat: To check distortion in EWL tunnel segments involving increase in horizontal diameter increase and decrease in vertical diameter. The effects are like ovalisation. However, in this case, the tunnels had already squatted when taking up the ground loads. Therefore, the remaining tolerable movement was the difference between the existing squat and the tolerable squat.
- Stepping & Opening of Circular Joint: In the longitudinal profile, the tunnel tends to have two types of deformation modes a) Bending mode of deformation and b) shear mode of deformation. Based on the type of behaviour, it is possible to have either opening of joints or stepping between the segments.

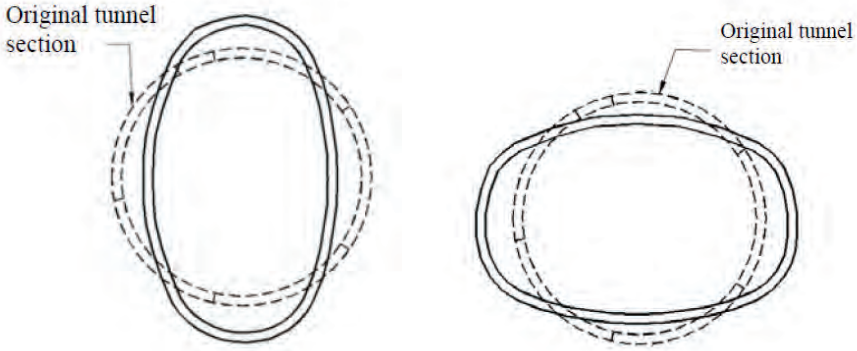
Figure 6 illustrates the different structural limit states described above for damage / impact assessment of existing tunnels.

3.1.3 Jacking force

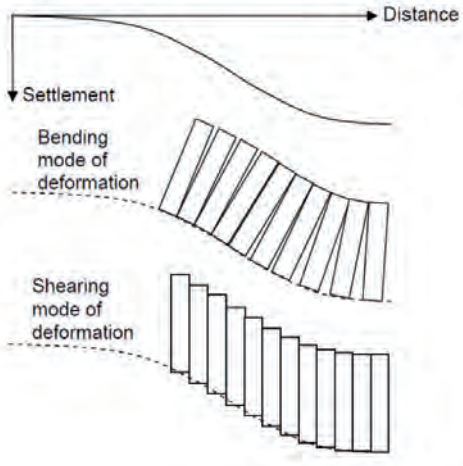
Minimum jacking force is calculated based on minimum required force to overcome the skin friction along the pipe contact surface area and maximum jacking force is calculated based on pressure transmission along the steel pipe and joint configuration between the pipes using ATV nomograms (Röhner et al 2010). Figure 7 illustrates the components considered for estimation of jacking force.

3.1.4 Factors influencing face stability during pipe jacking

Face stability calculations are required to determine the likelihood of the excavated face moving or collapsing into the void created during excavation. Face stability depends upon the type and variability of the ground being excavated, the ambient stress and ground water conditions, the rate of advancement and the construction methods adopted. The methods for calculating stability of tunnel faces are generally well-established and are adjusted for pipejacking / microtunnelling in terms of rate of advance, size of face and face support conditions. Face pressure of 1.2 bar to 2.2 bar is recommended based on the soil condition at face and the depth of the pipe.



a) Ovalisation and Squat



b) Stepping and opening of circular joint

Fig 6. Structural Limit states considered for existing tunnels

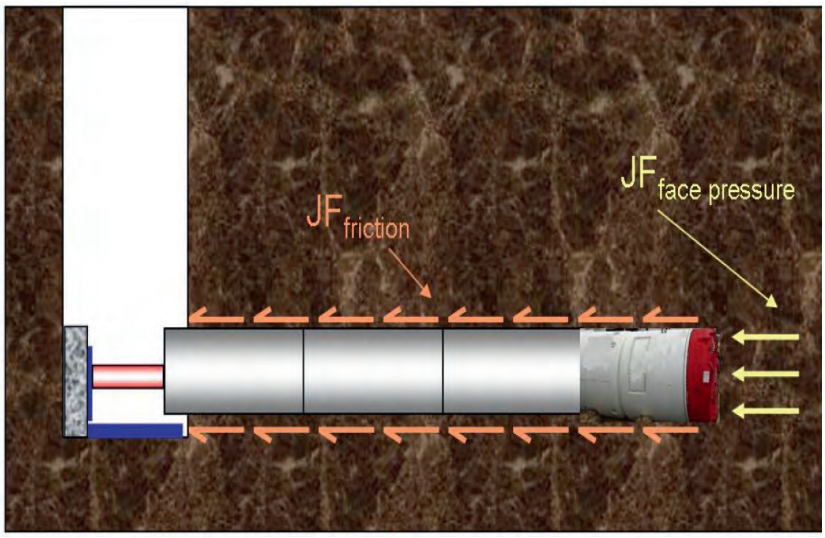


Fig 7. Jacking force estimation

Fig 8. Site constraint for movement of excavators

3.1.5 Machinery & Equipment

Because of the size of the support frames, the clearance between the vertical members had to be carefully checked for excavation, turning and reversing of the excavators along the Linkways. During the excavation, the diagonal member in the support frames were sequenced to allow the movement of vehicles. Figure 8 shows the tight site constraints faced during the excavation.

To ensure proper contact between the frames and the pipe-roof, grout bags above the frames were included as design element. In addition, jacking up of the frame using hydraulic jacks and temporary additional vertical members were carried out. The frames are jacked up and shim plates are installed in the gap created by jacking and the bolts are tightened and sealed. The temporary additional vertical members are reused for next frame jacking.

3.1.6 Monitoring and instrumentation of Linkway 1

To clearly understand the actual ground response during Linkway 1 excavation, a series of real time prism targets were installed within the operational tunnels and were monitored by automated robotic total stations installed within the tunnel. Each monitoring array consists of five prism targets (as indicated in Figure 9) to understand the movement of tunnel as well as to understand deformation in the tunnel shape (if any).

An automated site specific data visualization tool as proposed by Senthilnath G T (2017) was developed for this project to represent the change in shape and longitudinal profile of the tunnel as the Linkway1 tunnel excavation proceeds. The data visualization tool indicated uniform settlement of all the points (in a given cross section) which indicates there was no ovalization or squatting of the tunnel. Hence longitudinal profile settlement (i.e stepping and opening of circumferential joints) was critical during the Linkway 1 excavation. Figure 10 (a) and (b) presents typical prism readings in cross-section and longitudinal section of the tunnel alignment.

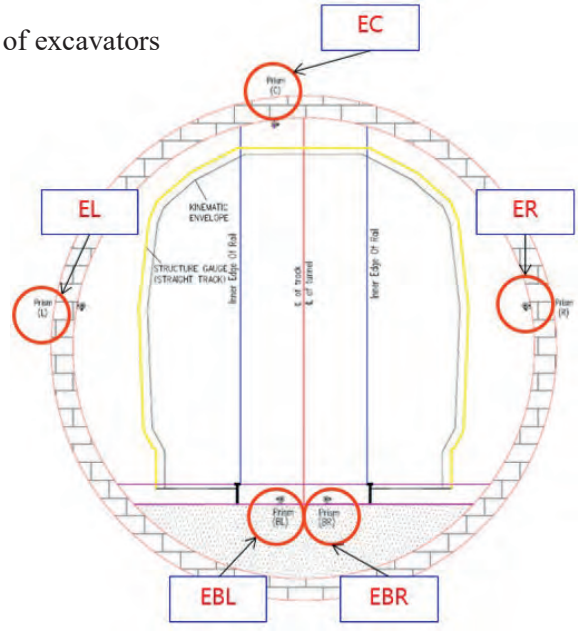
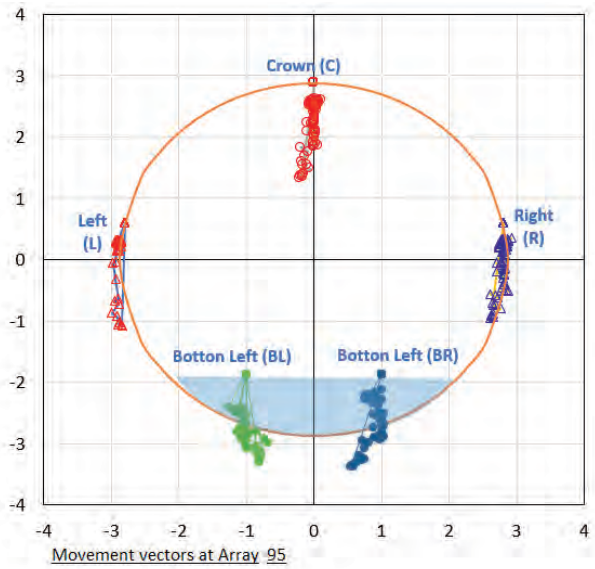
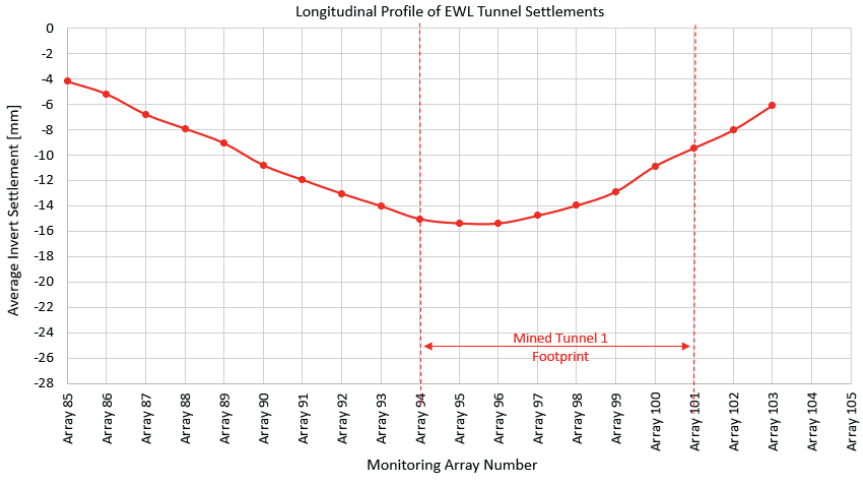


Fig 9. Prism monitoring locations



(a) Tunnel displacement in cross section



(b) Tunnel displacement in longitudinal section

Fig 10. Tunnel movement visualization

3.2 Linkway 2

As shown in Figure 11, the Linkway 2 excavation starts from the TSL platform box (by creating an opening in the D-wall) and the excavation proceeds below the existing EWL station base slab. Excavation was planned with steel support frames installed to underpin the base slab as the excavation progressed. However, as the excavation height is more than 10m, the excavation face is divided into top heading and bench excavation. The load transfer of underpinning members during bench excavation is ensured using a truss arrangement as shown in Figure 12 (the truss arrangement is not shown in the 3d render for clarity) The steel frames along with shotcrete sprayed on side walls and invert resist the lateral earth pressure and uplift pressure from the invert in Linkway 2 in the temporary stage. To check the composite behaviour of steel sets with shotcrete lining, the forces from the analysis are cross checked against the capacity curve derived based on Carranza-Torres and Diederichs (2009).

For simplicity, contribution of wire mesh in the bending capacity of the shotcrete lining is not considered. The forces obtained from composite – unit width model is split between Steel frame and shotcrete based on their EI and EA ratio for the design capacity checks.

3.2.1 Impact on station slab

The Linkway 2 excavation is carried out below EWL structure which was built in 1980s. The structure was designed using the former British code of practice CP110 which was later superseded by BS 8110. Despite this, current design checks in the EWL slab due to Linkway excavation was carried out as per the latest BS 8110. To understand the impact of Linkway construction on the slab, it was necessary to understand the in-situ stresses in the structural members of the EWL station. For this purpose, the client had used Autodesk Robot to create 3D Finite Element (FE) models of the existing EWL station. This model is used to understand the existing condition at various reference sections along the Linkway tunnel.

The additional stresses due to Linkway 2 excavation is estimated based on free span and column loadings on the slab. In addition, to limit the centre stress in the slab, an intermediate vertical support is proposed for the main branch of excavation in temporary case. A 2D PLAXIS analysis is carried out to estimate the maximum ground displacement and slab movement due to mining activity. Without any face support, for 1.5m round length and 7m wide excavation, ahead-of-face ground relaxation is estimated to be in the range of 50 to 55% (based on Panet and Sakurai formulation). However, because of face bolting, ground relaxation of 30% is considered in the FE analysis. Maximum EWL slab displacement is estimated to be less than 5mm.

3.2.2 Face Support and Grouting

Design of tunnel face reinforcement is made

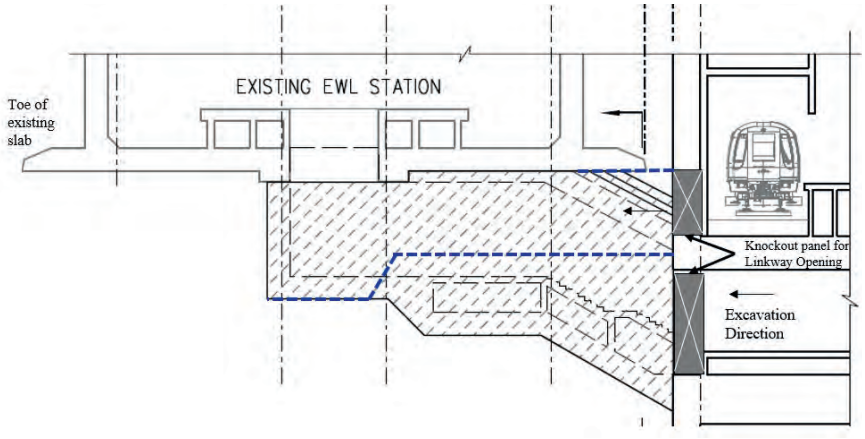


Fig 11. Excavation of main branch of Linkway 2

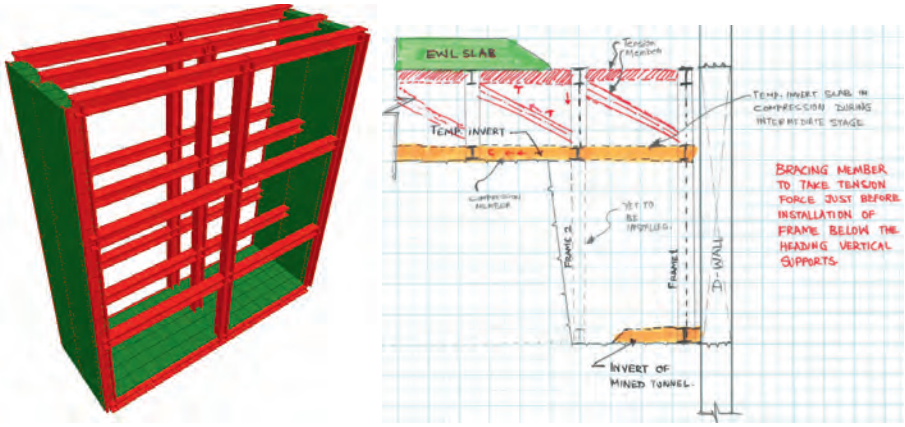


Fig 12. 3D render of underpinning system and load transfer system in truss member

to limit the ahead of face ground relaxation. The tunnel face reinforcement ensures that the unsupported span of EWL slab is maintained to a minimum length of less than 2.5m (1.5m round length + 1.0m allowance for slope/ground relaxation zone). Stability of face is based on limit equilibrium of a failure mechanism that consists of a wedge and a prism. Mohr-Coulomb failure condition is assumed for the ground. Inclination of the slip plane depend on the shear strength and on the stratigraphy of the ground and has been determined iteratively. The slip plane which results in maximum support requirements is considered for the face support requirements. During the ongoing excavation (without anchorage plates), the supporting effect of the face bolts relies solely on the strength of the bond between grout and soil. If anchorage plates are present (during an excavation standstill) and the bond length inside the wedge is insufficient, the bolt force will be transmitted to the ground through the plates. Minimum number of face support bolts are calculated based on limit equilibrium check and design based on nomograms by Anagnostou et al (2007).

3.2.3 Monitoring and instrumentation of Linkway 2

To monitor the ground performance during Linkway 2 excavation, a series of settlement markers were installed on the EWL base slab and in addition, strain gauges were installed on the alternate support frames to measure the axial loads coming on the steel sets. Except for the T-Junction (between the main branch and the side branches) axial loads in all the support frames were well within the prediction. This could be attributed to conservative approach used for loading consideration on the EWL slab to avoid utilizing the EWL slabs to their structural limits.

4. Discussions and Conclusion

Experience gained during the construction of the Linkway confirmed that if dry conditions are maintained, the Jurong formation (Sandstone, siltstone and mudstone with varying degrees of weathering) is a good material for tunnel excavation with advance roof support. From the observation of the ground performance during tunnelling, it became very clear that Jurong formation with high SPT blow counts is fairly incompressible and as anticipated, it experienced limited plastic settlements during the load redistribution in the ground. The actual ground movements due to pipe roof installation slightly exceeded the design prediction however the measured settlement during the Linkway excavation agree well with the prediction. The instrument readings suggested that influence of Linkway 1 excavation had a temporal variance as the excavation progressed. This suggests that a detailed analysis of response at each stage needs to be studied for a project of similar nature. The final ground response is not necessarily the most critical movement during the Linkway 1 excavation.

Currently temporary works for both the Linkway tunnels are completed and permanent works RC casting is in progress. For the successful completion of construction activities within the railway protection zone, very detailed sequence planning, periodical interface meeting with other designers and full compliance with requirements of the Code of Practice for Railway Protection works and/or railway operator was of utmost importance. This has ensured minimum disruption to the operation of the railway system.

Acknowledgement:

The Authors express their sincere gratitude to the Owner, Land Transport Authority of Singapore, the contractor Daelim Industrial Corporation and Geoconsult for their support during the project. Copyrights of the images taken from publicly available resources rests with the original author.

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CSMA Showcase

14th June 2019 Gold Coast, Australia

Thirty alumni from the Camborne School of Mines stepped away from their offices, mine sites and construction projects on Friday 14th of June 2019 to reunite and share their industry experiences at the first CSMA Showcase event, held at the Surf Club Broadbeach on Queensland's Gold Coast, Australia. Delegates traveled from New Zealand, Western Australia and across the East coast for this groundbreaking event, the first of its kind. "Sharing lessons learnt from the ranging experiences of CSMA alumni" was the theme founded over beer in 2018 at a Brisbane sundowner between Huw Rossiter, Anthony Bennett, Richard Buckingham and Diane Mather, supported by Mike Moore CSMA chair from across the shores. This group worked tirelessly together while new additions to families and tenders in Hong Kong were also completed, the event day unfortunately missing Anthony Bennett due to the successful delivery of twins (congratulations).

CSMA Gold Coast Showcase attendees group photo

CSMA Showcase Organizing Group Richard, Diane, Huw, Mike

The morning began with CSMA guest Mr. Dallas Adams delivering a pre-start safety talk on "Why Safety Matters "a heartfelt safety moment based on some very personal experience. Then followed a presentation by Richard Murrell openly sharing his recent experience in workforce health and safety, and how the mining industry is starting to recognize some of the challenges faced by its employees.

Mike Moore, CSMA Chair, kicked off the showcase presentations with The Keynote: "Founding and taking an exploration company public - lessons whilst they are still fresh in my mind". This was an inspirational and passionate story of the journey and growth of Golden State Mining, and the calling upon of a large network of people far and wide to get to public status. The important message within being the development and nurturing of a strong network, which although challenging at times is vitally important.

The Keynote presentation was followed by eleven spectacular presentations from CSMA Alumni that made it an engaging and thought-provoking day, which was certainly the intent of the showcase. Experiences were shared from Mining, Civil Engineering, Exploration, Geology, Safety and Tunnelling, discussions and stories were also shared amongst the delegates with some good probing questions being posed by the delegates.

The presentations given during the day were:

- TBM Decline at Grosvenor Mine (Queensland) – by Richard Murrell
- Exploration at Cue (Western Australia), exploring in a historically mined region – by Geoff Willets
- Design and Construction of Australian Tunnels – by Diane Mather and Richard Buckingham
- The Nitty-gritties of due diligence, the mining/technical aspects – by Alex Thin
- Developments in the value proposition of borehole geophysics; new sensors and automation – by Huw Rossiter
- Using Surface Seismic Interferometry to Locate a Large Underground Void – by David Matthews
- Value of GML Real-time Technology in Tunnelling – by Benny Chen of Orica (standing in for Peter Ayres)
- Research and Emergency Technical Support for the Queensland Mining Industry – by Gareth Kennedy
- Kidston Mine Hydro Project – by David Medcalf

This showcase event was made possible and great value due to the very kind support of the sponsors, so we would like to take this opportunity to again thank our Gold Sponsor Geobrugg, and our Silver Sponsors Axis Mining Technology, CSG and MPC Kinetic.

Thank you also to Joan Crowburn-Jones , of JC Creations, for being the official photographer.

The day's proceedings were finished off with a relaxed Sundowner at the Glenelg Public House over a few drinks and food, where more memories and stories were shared.

The next CSMA Australian event is the 2020 Dinner in Western Australia- look out for details coming soon.

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ATS Victorian Chapter Technical Presentation,

Wednesday 31st July 2019 –

TRENCHLESS CONSTRUCTION CASE STUDIES

On the evening of Wednesday 31st July, a presentation was given by David Medcalf of John Holland Tunnelling on recent trenchless construction projects in Victoria and Queensland. The presentation outlined key project facts and went into detail on some of the challenges faced during construction of these tunnels, and how they were overcome by the project team.

The following case studies were presented by David.

- Epping Main Sewer, Victoria, for Yarra Valley Water
- Kalkallo Creek Main Sewer (Section 1E), Victoria, for Yarra Valley Water
- O'Shannassy's Reservoir Outlet Renewal, Victoria, for Melbourne Water
- Gold Coast Seaway, Queensland, for Gold Coast City Council

A summary of the case studies presented is provided below.

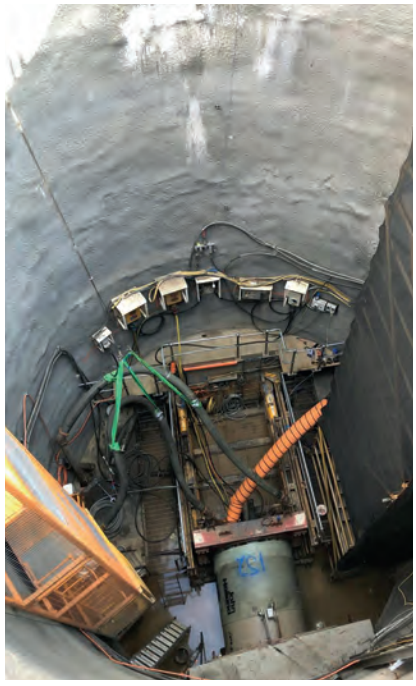
Epping Main Sewer Project

The project has recently finished its tunnelling works and is now in the process of completing manholes. Tunnelling was undertaken using two TBMs, an AVN1600 and an AVN1400 for a total tunnelling length of 2.3km, and the jacking pipe was GRP. In addition, there are five manholes and two vortex structures along the alignment, again of GRP construction.

Tunnelling was carried out through weathered Basalt and Melbourne Formation Siltstone / Sandstone materials, and for the greater part of the alignment good tunnelling rates were achieved in both materials.

The key challenge on the project was encountering Highly Weathered Melbourne Formation towards the end of the final drive at a depth of around 40m. The Highly Weathered material was of low strength and consequently relaxed onto the jacking pipe resulting in greater resistance to tunnelling, thus increased jacking pressures were required to advance the pipe string to the point that advances became very slow. This issue was overcome through the modification of an inter-jacking station with additional jacking cylinders and reinforcement, which was ultimately enough to allow the machine to continue its advance and complete the drive to the reception shaft.

High groundwater pressures and inflows were also encountered through the Highly Weathered Melbourne Formation, and it was necessary to relive the water pressure through the lining to reduce the groundwater load being imparted onto the jacking pipe.



Kalkallo Creek Main Sewer Project

Tunnelling has recently completed, and the team is now in the process of installing the three GRP manholes. Tunnelling was carried out through weathered Basalt for the installation of 1150m of DN1600 GRP pipe. Due to the favourable ground conditions high excavation rates were achieved.

O'Shannassy's Reservoir Outlet Renewal Project

The project is currently preparing for tunnelling works with site establishment and launch and reception structure preparation ongoing. Tunnelling is scheduled to commence in September 2019.

The tunnel will be 425m long, and will be excavated using an AVN 1800 pipe jack TBM using a concrete jacking pipe, with a Mild Steel Concrete Lined (MSCL) product pipe installed upon completion of tunnelling. Ground conditions for the tunnelling are expected to consist of Fresh to Highly Weathered Rhyodacite and Ignimbrite, which will likely be challenging due to the high

strength of the fresh material. Both igneous rock types are expected to have a high Quartz content and high strength, up to 260MPa, it is therefore expected that high cutter disk wear will be one of the key challenges to be managed during tunnelling.

Gold Coast Seaway Project

The project is currently preparing for tunnelling works with site establishment and the launch and reception shafts under construction. Tunnelling is scheduled to commence in mid-October 2019.

The launch shaft in Quota Park is very close to the sea, so it is being constructed as a piled shaft, where one of the construction challenges is sea water ingress in-between the piles. The reception shaft on the south end of South Stradbroke Island is being constructed using the pre-cast segmental caisson technique through alluvial sands.

The tunnel will be 1,400m long, and will be excavated as a single straight drive due to its alignment below water, and because this is an environmentally sensitive area that precludes alternative means of pipeline construction across the waterway. Excavation will be undertaken through sandy clay using an AVN 2000 pipe jack TBM using a concrete jacking pipe, with a GRP product pipe installed following tunnelling works. Challenging ground conditions in the form of alluvial sands are expected to be encountered in the latter half of the drive where the sandy clay profile drops.

This was a well-attended technical session, and there was good group discussion in the Q&A session at the end.

2019 Tunnel Systems Workshop Wrap Up

On July 18th the ATS Queensland chapter hosted a one-day workshop on Tunnel Systems which was held at the Novotel in Brisbane. The workshop brought together industry leaders in the field of Tunnel Systems to share first-hand experience on the design, construction, operations and maintenance of tunnel projects. In total 76 delegates attended the event in what was a fantastic day full of engaging and informative presentations. It was great to see a mixture of practitioners attend from Clients, to Builders, Consultants and Suppliers.

Silica Dust Control

Kate Cole moved the audience with an excellent presentation about silica dust control in tunnelling works. Kate shared some of her own experiences working in the industry from the UK and locally from Sydney Metro. She is the key person behind the ATS Clean Air Working Group and shared the excellent publications which are available on the ATS website under Resources on best practice for Silica Dust Control.

Operations and Maintenance of the Sydney Harbour Tunnel

Bob Allen captivated the delegates with his experiences from the O&M of the Sydney Harbour Tunnel over the last 20 years. The Sydney Harbour Tunnel is perhaps the busiest tunnel Australia providing a vital link under Sydney Harbour. Bob shared priceless first hand experience on what is involved in operating a tunnel on a day-to-day basis. He also shared footage of the in tunnel emergency drills used to train their operators and test their emergency systems.

Moving People Safely Underground

Derek Edwards and Christopher Baker gave an insightful talk on the systems that are involved in tunnels and which are fundamental to moving people safely. Derek shared with the audience insights into M&E systems for road tunnels and the functionality of getting it all to work. Chris showcased his technical expertise as a M&E Design Manager from major rail projects. This included providing the audience with in depth understanding of the safety systems and differences between metro, regional and freight rail projects.

Ventilation and Cooling System Design Underground

Leon Van den Berg gave the audience an excellent presentation on the design of underground ventilation and cooling systems. Leon share his first hand experience in designing ventilation and cooling systems for underground mining projects and showed just how important it is to keep the fresh air flowing. Delegates gained an excellent understanding of ventilation design and management for underground construction works.

Operational Readiness for Tunnels

Conrad Stacey showcased his depth of understanding with an informative presentation on the operational readiness of tunnels. Conrad highlighted experiences in delivering large scale tunnel projects and explained well the current short-falls in operational testing of tunnels. He left the audience with a handful of excellent points on how to improve the readiness of tunnel project.

Moving Tunnel Systems into the 21st Century: Seamless Integration and the IoT

Matthew Taylor delivered a reality check to the delegates of where we should be as a industry with delivering large scale tunnelling projects. Matthew gave a case example from the O-Bahn Tunnel in Adelaide where the Clients requirements for minimal maintenance costs drove the use of smart infrastructure on a project with low capital cost. He also demonstrated the need for Clients to lead and drive innovation in major tunnelling projects.

A special thanks goes out to the event sponsors and organisers. In particular the ATS Queensland Chair Diane Mather who was instrumental in organising the event.

Austroads Road Tunnels Task Force

Austroads is the peak organisation of Australasian road transport and traffic agencies. The Austroads Road Tunnels Task Force consists of jurisdictional representatives from around Australia and New Zealand, and representatives of the Australasian Tunnelling Society (ATS) and Australasian Tunnel Operators Group (ATOG).

The Task Force is responsible for considering all aspects of tunnel planning, design, construction, operation and maintenance. It coordinates updates to the Guide to Road Tunnels and coordinates the development of technical research projects.

The Austroads Board has approved two new road tunnels projects for 2019-10:

- **ART6137 Use of Perceptual Countermeasure Treatments to Reduce Crash Risks in Tunnels** will evaluate the application of low-cost perceptual countermeasure (PCM) treatments in tunnels to improve driver speed behaviour and lane discipline, thereby reducing crash risk.
- **ART6151 Revision of Austroads Guide to Road Tunnels Part 2: Planning, Design and Commissioning** will review in-tunnel emergency equipment for public use; provide a systems engineering framework for delivery of new tunnels; address human factor considerations in design, operations and maintenance; detail recommended egress signage; consider the impacts of emerging technology such as electric vehicles, autonomous vehicles and communication equipment; and provide a standardised approach to collecting incident and crash data in and around tunnels.

This year the Task Force has overseen the delivery of four major publications.

New tunnel retrofitting guidance

There is an increasing need for tunnels to be retrofitted rather than maintained, due to excessive congestion on roads around tunnels, deteriorating structures, technological improvements and demand for higher standards of safety.

As a result, Austroads has produced a new Part 4 to its Guide to Road Tunnels to support road agencies when they are retrofitting or refurbishing tunnels, or replacing assets in tunnels, in Australia and New Zealand.

"Part 4: Retrofitting Tunnels provides guidance on when refurbishment is needed and the types of refurbishment that can be considered," says Les Louis, principal author and ARRB Associate. "The Guide provides processes for developing project requirements, geometric considerations relating to cross-sections, and information on traffic management functions including signs and lighting.

Part 4 also contains guidance on fire protection and evacuation systems, mechanical systems including pumps and lifts, electrical and electronic components including tunnel management systems and power supply, and energy efficiency."

Principles and standards are based on experience across Australasia and in other countries where tunnels have been operating for many years.

"Practices from other countries have been considered in the context of Australian and New Zealand conditions, experience and legislative requirements," says Les.

Guide link: Guide to Road Tunnels Part 4: Retrofitting Tunnels

New pavement guidance for tunnels

A new edition of Guide to Road Tunnels Part 2: Planning, Design and Commissioning includes significantly expanded pavement design guidance.

Tunnel pavements include:

- Surface roads – conventional granular with a thin wearing course, flexible and concrete pavements.
- Pavements within tunnels and designed as a conventional pavement.
- Pavements that are structural slabs or floors and designed like a bridge.
- The ramp leading into a tunnel, typically a 'U" shaped structure where the walls and base are reinforced concrete and the pavement is the structural reinforced concrete floor with an asphalt wearing course.

It is expected that the Guide will be used by engineers and technical specialists in tunnel technology working on the planning, design and operation of road tunnels, proponents of road tunnel solutions, senior decision makers (in an overview role) and regulators in the various jurisdictions associated with the construction of tunnels.

The pavements update was authored by George Vorobieff.

The PDF version of the Guide is available to download for free and the updates have been incorporated into the online version of the Guide.

Guide link: Guide to Road Tunnels Part 2: Planning, Design and Commissioning

Assessing the risks of transporting dangerous goods in tunnels

Dangerous goods are items or substances which are a risk to health, safety, property or the environment such as petrol, liquefied petroleum gas, paints, pesticides and acids.

The most common approach to transporting dangerous goods is on roads however, this can be contentious, especially when navigating through sensitive infrastructure such as bridges and tunnels or when the route is near schools or hospitals.

In June Austroads published a report that sets out a framework for undertaking risk assessments of transporting dangerous goods in road tunnels.

While the transport of dangerous goods carries some inherent risk, banning dangerous goods from tunnels can shift this risk to other areas that may increase the overall risk profile and have an economic impact.

The report provides an approach for road managers to compare the societal benefits of using a road tunnel or another surface route across a complete journey. It also provides information on the application of design methods to reduce risks.

It is expected that Stage 2 of this research will review and further expand on this topic. The project is due to be completed in mid 2020.

Dangerous Goods in Tunnels: Literature Review documents the results of an extensive literature review involving international and local studies and methodologies, trial reports, and media.

Dangerous Goods in Tunnels: Application and Methodology documents the framework and considerations to be applied in undertaking the dangerous goods risk assessment.

New fire data set for major Australian road tunnels

In March 2019 Austroads published a detailed reference document for fire incidents and fire safety operational information for eleven major road tunnels in Australia.

The eleven major road tunnels which form the basis of the study are all more than 1km in length, have high traffic volumes, are in an urban location, and are monitored and controlled through a continuously staffed control centre.

As the incidents are logged through the operational management control system, the data collected is highly accurate and includes minor incidents. The high-quality data set captures extensive information

about 78 fire incidents in Australian road tunnels. The data capture extends from the opening date of the Sydney Harbour Tunnel which opened in August 1992, to include subsequently opened major tunnels and their operation up to and including June 2016.

The information provided includes the frequency of fire incidents, the types of incident vehicle, the estimated fire size, the means of detection, the way the fire was extinguished, the time it took to extinguish the fire and reopen the tunnel, and whether operators deployed an emergency evacuation of the tunnel.

It is envisaged that this specialised data set will be used as a reference in both the development of projects to inform designs and design standards, and in tunnel operations to demonstrate the effectiveness of the fire safety measures deployed. It captures the extent of use of fixed fire fighting (deluge) systems and so can be used by an international audience considering the use of these systems.

The study identified a need for a consistent method of reporting on fire incidents using pre-determined terminology. While Australian Standard AS2577 provides a process it is considered too complex for this purpose. A simplified fire incident questionnaire is included in the report, to enable future incidents to be easily added to the base data set.

It is envisaged that the data will be periodically updated to reflect the continued operation of the existing eleven major tunnels. Future versions will also include road tunnels opened after July 2016 such as the Waterview Tunnel in Auckland.

Download the report at: Fire Incident and Fire Safety Operational Data for Major Australian Road Tunnels

Takeaways from 'PPPs and D&Cs - A Case Study: Inland Rail'

Young Member, Chelsea Simanhadi, Graduate Engineer at Aurecon, attended and reports from the Technical Session - 'PPPs and D&Cs - A Case Study: Inland Rail' - an event hosted by the Civil College, College of Leadership and Management and Railway Technical Society of Australasia.

The event went through the general overview of the Inland Rail project and included speakers from different sides of the table:

- Rob McNamara, the project director of the North Star to Border and Border to Gowrie projects which will be delivered as a design and construct (D&C) contract.
- Tony Lubofsky, the PPP director of Inland Rail, speaking about the Gowrie to Kagaru section of Inland Rail which is expected to be delivered as a Public Private Partnership (PPP)
- Jon Davies, the CEO of Queensland Major Contractors Association (QMCA) who shared his perspective on risk transfer and allocation on both the D&C and PPP.

PPP and D&C

As a recent graduate working in industry I have heard the acronyms thrown around however until now I have not really understood the meaning in relation to the Inland Rail project.

In Summary:

Design and Construct (D&C) is a traditional delivery method that involves the government producing a project specification and calls for tenders from the private sector D&C contractors to construct the project per the specified project requirements for a fixed price.

The Public Private Partnership (PPP) model as the name suggests is a partnership between the public and private sector that involves:

- Private sector finance
- Whole-of-life service from design, construct and maintenance; or as Tony describes it; 'A D&C with bells and whistles'.

The PPP Case Study: Gowrie to Kagaru

Tony discussed that the PPP model has the following benefits:

- PPP = Innovation. The healthy tension created within the consortia, provides an environment to innovate and improve outcomes for the whole-of-project lifecycle. Particularly for the Gowrie to Kagaru section which encompasses 58 rail bridges and 8km of tunnels, including the 6.5km tunnel through the Toowoomba Range.
- Optimised risk transfer. Risks are allocated appropriately to minimise the cost of managing the risks and maximising outcomes for each party.

On the other side of this, the PPP model has the following disadvantages:

- The PPP model can present increased complexity by involving the government, designers, contractors, financiers and maintainers. Furthermore the transaction costs involved in a PPP are greater.

The D&C Case Study: North Star to Gowrie

North Star to Gowrie (NS2G) comprises of North Star to Border (NS2B) and Border to Gowrie (B2G). The D&C has multiple interfaces including: stakeholders, approvals, utilities, rail crossings and working with adjacent projects. Rob discusses the following points as the advantages of the D&C model for B2N and NS2B:

- Flexibility to adapt with changing political shifts, election cycles and the expectation of social performance.
- Keep up with the changing market capacity and competing with other major projects. The D&C model enables them to engage smaller subcontractors, adjust the need between Tier 1 and Tier 2 companies and create local jobs.
- The requirement to be flexible on this D&C is proof that the D&C model still has drive for innovation.

In terms of risk, the D&C model enables:

- a single point of management and responsibility
- sharing risks across design unknowns at post-approval stage.
- sharing unknown community risk throughout design and construction phases.

Risk Transfer and Allocation

Jon Davies discussed that the one risk that cannot be transferred is reputation risk where the D&C and PPP both have this risk however, when something goes wrong, the government will still be blamed. Risk transferred to contractors does not mean less cost for the government. He also adds that in major infrastructure projects, risk management is an ongoing issue and that the process of risk management should be ongoing with added validations.

Jon also mentioned the Project 13 initiative started in the UK where which is an industry-led initiative seeking to develop a new business model based on an enterprise to boost certainty and productivity in delivery.

In summary.

There is no definitive answer whether a PPP or D&C model is better for a project. It is highly dependent on numerous factors, complexity and risk management required for each project. The case studies presented at this event were great examples of how the two models are adopted into two different complex sections of the Inland Rail each with their unique requirements.

TBM and tunnelling challenges in mixed ground and limestone karsts in Malaysia

Dr Ir Ooi Lean Hock and Gusztav Klados gave an interesting and engaging technical presentation to ATS QLD and NSW chapters in July 2019 on the TBM and tunnelling challenges faced in mixed ground and limestone karsts in Malaysia. Diane Mather ATS QLD Chair Summaries the events:

A much-needed solution to mitigate flooding in Malaysia's capital city has led to the innovation of the dual-purpose SMART tunnel, which diverts storm water and doubles as a tolled motorway tunnel. The mass rapid transit (MRT) lines were also developed to mitigate traffic congestion in the CBD. Sections of the metro lines cross the city underground in TBM excavated tunnels. Substantial sections of the infrastructure were undertaken in challenging Kuala Lumpur Limestone. This limestone has buried tropical karsts, complex three-dimensional network of solution features, highly variable rock head, steep sided troughs and cavities.

Dr Ooi began the technical session with a detailed overview of the project geological setting and Geotechnical and Geophysical Site Investigation methods for the project.

A project outcome was the development of the Variable Density Tunnel Boring Machine, a slurry machine developed for several modes of tunnelling in both slurry and earth pressure balance with a facility to vary the slurry. The Variable Density development has led to a technical innovation that is the first of its kind in the world. The increased levels of function automation and controls in the VD TBM were introduced from lessons learnt during the course of tunnelling through limestone Karsts on the SMART tunnel and MRT projects in Kuala Lumpur, Malaysia.

Dr Ooi gave a detailed overview of the project geological setting

Gus discusses the technical challenges of the TBM drives

About the Speakers:

Dr. Ir. Ooi, Lean Hock

Ooi has over 30 years of experience in geotechnical engineering design and construction. Over the last 20 years, he has managed geotechnical design and construction of major infrastructure projects in South East Asia and Middle East. Underground experience include deep excavation works, cut and cover structures, TBM and drill & blast tunnels as well as pipe arch tunnelling. Recent projects include Klang Valley MRT SSP and SBK Line, the Electrified Double Track Project (Padang Besar to Ipoh), SMART Project, NDIA Airport, Dukan Highway (Doha), Sitra Causeway (Bahrain), Nam Theun 1 HEP (Laos) and Pergau HEP.

Gusztav (Gus) Klados

Gus has over 40 years' tunnelling experience in multicultural environments as a contractor, consultant and client. He has worked in Europe, India, South Africa and South-East Asia on water and rail projects in various management positions from Tunnel Manager to Project Director, on projects such as the Channel Tunnel, Klang Valley MRT SBK Line, Budapest Metro Lines 3 & 4, Athens Metro Lines 2 & 3 and Calcutta Metro sections 4/A and 2/B.

ATS would like to thank GAMUDA.

ATS Victorian Chapter Technical Presentation,

Wednesday 26th June 2019 –

Satellite based ground deformation monitoring

A technical presentation was given by Eric Audigé on the evening of Wednesday 26th June 2019, on the subject of satellite based ground deformation monitoring. Eric is the Managing Director (Oceania) of Sixense, an international company specialising in digital solutions supporting the construction, civil engineering and infrastructure management markets.

The presentation addressed the subject of radar satellite interferometry (InSAR) and how the technology can be used to assist in ground monitoring works. In urban tunnelling projects, ground deformation control and monitoring are important to guarantee that the different infrastructure assets crossing or adjacent to the tunnel alignment, as well as other new build elements, are not affected by the construction activity in the short or long term. Radar satellite interferometry (InSAR) is a non-invasive surveying technique which is able to measure millimetric motion of terrain and structures over wide areas, and brings to the user a comprehensive, consistent and periodic vision of ground deformation without any need to access site.

In his presentation, Eric initially explained the science behind the satellite based ground monitoring technique and what type of data is collected during satellite passes, as well as the different resolution or accuracies available. He then outlined the relative differences in factors such as accuracy, coverage and cost effectiveness of satellite based ground monitoring versus traditional manual surveying and automated total station survey methods.

Eric also presented a number of global case studies where satellite based ground deformation monitoring has been undertaken, and how the technique assisted those case study projects in understanding the 'big picture' extent of ground movement. These case study projects included Cross Rail in London, the Elizabeth Line, being a major tunnelling project under the capital passing below many historic buildings. This case example detailed the application of the monitoring technique through the different phases of the project, and highlighted the added value for the parties involved in the project.

75 people registered for and attended this presentation, and there was a good Q & A session at the end.

Queensland Group Report

2nd Quarter 2019
Mrs Diane Mather, Chairperson Queensland ATS

Activity	Outcome/Report
AGM held Thursday 15th November 2018. The 2019/2020 committee nominations were accepted.	**2018 QLD ATS Committee** Chair – Diane Mather (Standards Australia Rep) *Immediate Past Chair- Dr Harry Asche Vice Chair- Andrew Ridout Secretary - Stuart Schmidt Treasurer - *Jurij Karlovšek & Shotcrete Society Representative Young Member Representative – Monique Quirk, Brodie Aitcheson, Jiwoo Ahn (webmaster) Committee Members: Alan Robertson, Mark Claassen, Thanh Phan, Jeremy Kruger, Anthony Harding, Brendan Henry, Martin Cunningham, Tino Ferrero, Morteza Ghamgosar, Scott Keniston, Geoff Archer * ATS National Austroads Representative – Tony Peglas *denotes role on National executive
Technical Sessions & Events	**Technical Sessions 2019 to date:** Feb 14 2019 Austroads Taskforce update March 14th 2019 overview of the Westconnex projects March 28th 2019 – David Sugden – Young Members @ University of Queensland April 4th 2019 Dubai Metro Extension 9th May Sydney 2019 Sydney Heads Rail Tunnel 20th June 2019 Brisbane Geotechnical Borehole Database 18th July 2019 One day technical workshop- Tunnel Systems **Upcoming 2019 Events:** Tuesday 23rd July Tunnelling through Limestone Karts in Malaysia Thurs 8th August Bulimba Stage 2 Joint ASTT Wednesday 21st Aug Oberau bypass tunnel Thurs 12th September NBAQ4 Manila Thurs 18th Oct Tunnel waterproofing update Fri 19th October Golf Day 12th November AGM & Westgate Project Update – TBC 4th December St Barbara Day Function Regatta Hotel – Mates in Construction **2020 Proposed Events:** Sydney Metro Under Harbour TBM Crossing, Snowy 2.0, One Day workshop, St Barbara Day Function Typically sessions second Thursday of the month through 2018 venue the Hawken Auditorium at Engineers Australia Attendance is around 70 people.
Young Professionals	Proudly provided by the Australian Tunnelling Society Young Members, the authors of the top three David Sugden Writing Award winning entries will present a summary of their paper and provide insights into the award itself, including the value of technical development and mentoring in tunnelling. 5.30pm, Thursday 28 March 2018 University of Queensland St Lucia, Building 49: Advanced Engineering Building Following the Tunnel Systems Workshop July 18 (see below) an Evening Networking Function was hosted by ATS Young Members at the Poolside bar Novotel Brisbane sponsored by Hilti, BBE group and Aurecon. The session provided the opportunity for the young members to engage with the workshop delegates, speakers and sponsors in a relaxed social forum.
Industry	Cross River Rail has been awarded Tunnel and Station and RIS awarded to CIMIC group CPB, BAM, GHELLA, UGL JV. Brisbane Metro is on hold. Inland Rail PPP pending.
General	Stacey Rawlings General Manager for EA QLD has attended the QLD ATS committee meetings (2018). QLD Committee and working closely with EA QLD Division for upcoming events.
Student and graduate engagement	QLD ATS Chapter are working closely with EA and CSIRO promoting "The STEM Professionals in Schools" initiative. Further info can be accessed through the following CSIRO website https://education.csiro.au/sps/
Austroads:	Austroads Tony Peglas and Nigel Casey attended the Austroads meeting in Victoria- report submitted separately.
ATS QLD One Day Tunnel Systems Workshop	One Day workshop Tunnel Systems The ATS Queensland Chapter hosted a one day Workshop on Thursday 18th July at the Novotel In Brisbane. 75 delegates attended the engaging and informative day chaired by Tino Ferrero. The workshop speakers presented their first-hand industry experience in the areas of safety, design, construction, operations and maintenance for tunnel systems from recent projects in Australia. The wide range of topics included silica dust control, to optimising functional tunnel operations and maintenance in the Sydney Harbour Tunnel, moving people underground safely, and informed attendees with up-to-date tunnelling practices undertaken in real life projects. Speakers included: Kate Cole, ATS Clean Air Working Group, Bob Allen, Sydney Harbour Tunnel Operations, Derek Edwards, Tunnel M&E Design - Aurecon, Chris Baker, Tunnel Systems Discipline - Aurecon, Conrad Stacey, Stacey Agnew, Matthew Taylor, Leon Van DenBerg A special thanks to the major sponsors of the event: Normet, Bluey, BASF, Breathsafe The day was Followed by Evening Networking Function hosted by ATS Young Members sponsored by Hilti, BBE group and Aurecon.

The ATSym Sugden Roadshow

The ATSym had four stops (Melbourne 13/03, Sydney 20/03, Brisbane 28/03, Perth 06/06) to showcase the top three authors on the inaugural David Sugden Award Roadshow for 2018. Melbourne and Perth had very modest attendance, with a significantly healthier showing at the Sydney and Brisbane events. The event didn't have the drawing power of some of the other technical presentations and we struggled to gain traction with local universities, those who did attend spoke highly of all three presenters (Matthew Bennett, Aaron Lippett and Brodie Aitchson) and their technical presentations.

Congratulations to Senthil G T who has taken out the 2019 edition of the David Sugden Award with a paper focused on his design and construction experience in Singapore for a challenging pedestrian underpass.

A quick reminder that ATS membership is FREE for students, half price for first year graduates and a low $99/annum for full members.

As always you can keep in touch with the ATS via facebook and LinkedIn (@ AustralianTunnellingSociety) and keep an eye on the website for upcoming events in your area. If you are more interested in what young engineers are doing around the world then head to the ITAym Facebook page to grab a digital copy of the new edition of breakthrough, the publication is in it's 5th edition and continues to grow in its distribution and depth of content.

Happy Tunnelling
Keith Bannerman,
ITAym Steering Committee Chair & ATSym Chair

Victorian Chapter Report

2nd Qtr 2019
Richard Buckingham – Chair Victorian ATS

Activity	Outcome/Report
AGM **Held 28th November 2018** **2019 Committee nominations were accepted for 12 positions.**	**2019 ATS Committee** 2019 ATS VIC Committee Chair: Richard Buckingham Immediate past Chair: David Grist Deputy Chair: Stephen Barrett Secretary: Anthony Bennett Treasurer: Bruce Grant Young Member: David Suter Events Coordinator: Michal Fronek Committee Members: Gerry Bertakis, John Main, Nadin Makinm, Gerard Quigg, Jawad Zeerak, Jay Lee Due to the significant level of interest from ATS members in Victoria to join the Vic committee we were able to elect a specific ATC 2020 Organising Committee, which was a requirement anyway.
An ATC 2020 Organising Committee was also elected at the same time.	ATC 2020 Organising Committee Chair: Rob Muley Treasurer: Bruce Grant PCO/Venue: Andrew Kindred Marketing: Gerard Quigg Sponsors & Exhibitors: Yuqi Tan Revenue: Tong Joo Sia ITA: Rob Muley Technical Papers & program: Jiang Aizezi
Technical Sessions 2019	27th Feb 19: West Gate Tunnel - Ground conditions (attendance 165) 27th March 19: Metro tunnel construction in a complex urban environment subject to broad spectrum of geological and geographical conditions (attendance 121) 16th April 19: Sprayed concrete linings, fibre reinforcement, GFRP rock bolts, spray applied waterproofing membranes or numerical modelling (attendance 100) 1st May 19: A Sydney Heads Rail Tunnel (attendance 101) 29th May 19: Snowy 2.0 combined session with Victorian College Civil Branch (attendance 124) 26th June 19: Satellite Based Ground Deformation Monitoring (attendance 75) 31st July 19: Microtunnelling 28th August 19: Water Ingress in long TBM tunnels – its mitigation and control (co-host with AGS) 25th September 19: Noise and vibration – analysis and mitigation 30th October 19: International tunnelling projects or Risk in tunnelling 27th November 19: Hydrogeological Setting of Melbourne (also Vic AGM)
Young Professionals	Pending update from YM rep
Industry	Melbourne Metro Tunnel project ongoing Westgate Tunnel project ongoing Epping and Kalkalo sewer tunnel projects ongoing North East Link Project tender likely to come to market in Q4 2019
General	Planning well underway for the ATC 2020 conference in Melbourne, likely to be held in November (pending venue availability) ITA Tunnelling Awards will be held in conjunction with the ATC 2020
Student and graduate engagement	Need to continue working with local education institutions to spread the word of the ATS. A number of Vic ATS committee members have ties with such institutions which is a good link.
Incoming 2019 Vic Committee	Covered above

Western Australia Chapter Report

Jan – July 2019
Jayson Bebek

Activity	Outcome/Report
Committee	**2018 ATS Committee** Chair – Jayson Bebek Committee Members: Mike Bluck, Will Houghton (Young member Rep), Eric Hudson-Smith and Des Vliestra
Technical Sessions & Events	**Technical Sessions 2019 to date:** Feb21st 2019 - Developments in Mechanised Tunnelling – Dr Karin Bappler June 6th 2019 – David Sugden Winners July 25th 2019 – Engineering, Planning, Design & Construction Challenges on Recent Perth Tunnels – Robert Lowe **Upcoming 2019 Events:** Ground Freezing – Carlo Aruffo - Trevi Tunnels for High-pressure Gas Pipelines - discussing lessons across four different projects – Thomas Seeber - Atteris
Young Professionals	WA Chapter hosted the Sugden Award winners talks in June at the PTA Lecture Theatre.
Industry	Tunnelling on the Forrestfield Airport Link is progressing with both TBMs, Grace and Sandy on their final run towards Bayswater. Grace left the Redcliffe Station box in mid-June and Sandy in early August. Tunnelling is expected to be completed by April next year. The station boxes at Airport Central and Redcliffe are now being fitted out. The ACS box platforms have been formed and the escalators installed. At Bayswater the dive structure is complete and the internal emergency stairs and lift shafts. At Forrestfield the work on the station is well advanced with the roof structure taking shape above the station concourse. The tunnel portal building is also a roof stage and the railcar stowage facility well advanced. Work on the tunnel cross passages continues and the SI-NRW JV is currently preparing to commence ground freezing for the there cross passages beneath Perth Airport's airside areas.
General	The ATS Short course fee structure generated a number of new membership applications to access the lower fees available to members.
Student and graduate engagement	Planning is underway for student/graduate centric event to be held in Q1 2020.
ATS Tunnel Design and Construction Short Course	The three-day short course was held in Perth from June 16th to 18th at the University Club of WA, with 80 attendees registered. The course commenced with a site visit to the Redcliffe Station box at the Forrestfield Airport Link on the afternoon of Sunday 16th, with 40 of the registered course attendees getting a comprehensive tour of the station box, TBM and entrance to one of the tunnels. We are extremely grateful to SI-NRW JV and the PTA for their assistance in facilitating this visit. This was followed by two days at the University Club of WA covering a broad range of tunnel design and construction subjects. In all there were 18 technical presentations by local, interstate and international speakers including:Proffessor Arnold Dix (ALARP), Ulrike Pelz (NorthConnex Tunnel Project), Richard Mann (Johnstaff), Doug Stewart (Golder Associates), Alan Lundorf (Golder Associates), Babak Hamidi (Menard Oceania), Sarvesh Mali (Boral), Des Vliestra (Barchip Australia), Paul Petropoulous (Coffey), Steven Langley (GHD), CK Tsang (Aurecon), Lorenzo Facibeni (Geodata), Geoff Charlesworth (AECOM), Victor Ngo (Bluey), Oskar Sigl (Geoconsult Asia), Jiang Aizezi (John Holland), Peter Lamb (Coffey), Charlotte Ridley (SI-NRW JV) and Emilie Stenmark (GHD) A networking dinner was held on Monday night at the nearby Matilda Bay restaurant. The event would not have been possible without the generosity of our sponsors that included: Public Transport Authority, Salini Impregilo-NRW, Austunnel, Herrenknecht, Bluey, CREG, DGSI Slope Indicator, Golder, Geodata, Rob

NZTS H&S Course

The New Zealand Tunnelling Society (NZTS) recently ran a 3-day health and safety course in Auckland in recognition of the significant amount of tunnelling activity currently going on in the city. Two major tunnelling projects, City Rail Link and the Central Interceptor sewer project are in the early stages of construction as well as various small utility tunnel schemes.

The course which was delivered by Dr Donald Lamont, attracted 37 engineers, managers and health and safety professionals from Central Interceptor, City Rail Link, Auckland Council, Maconnell Dowell, Abergheldie Harker, Ghella, March Cato and Jacobs as well as receiving strong support from the high hazard unit of WorkSafe NZ – the health and safety regulator for NZ tunnelling.

Bill Newns Chair of the NZTS said afterwards, 'One of the main reasons to set up the NZTS and re-join the ITA was to improve our international links and access world authorities to help our industry grow from the delivery of successful tunnelling projects. It is very pleasing to see the strength of cross sector support for Health and Safety in New Zealand evident at this short course. We are grateful to Dr Lamont for sharing his deep knowledge and insights into emerging trends and technologies with us and we look forward to his return".

Australian and New Zealand Tunnel

Region	Location	Project	Client	Technical Advisor	Designer	Contractor
NSW	Sydney	NorthConnex	RMS	AECOM	Aurecon-SMEC JV	LendLease-Bouygues
NSW	Sydney	Westconnex Stage 1B (M4 East)	Sydney Motorway Corporation		Arcadis-MJA-PSM	CPB-Samsung-John Holland JV
NSW	Sydney	WestConnex Stage 2 (New M5)	Sydney Motorway Corporation	AECOM	Aurecon-Jacobs	CPB-Samsung -Dragados JV
NSW	Sydney	WestConnex Stage 3A (M4-M5 Link)	Sydney Motorway Corporation	AECOM	Aurecon-Jacobs	LendLease-Bouygues - Samsung JV
NSW	Sydney	WestConnex Stage 3B (Rozelle Interchange)	Sydney Motorway Corporation	AECOM		
NSW	Sydney	Sydney CBD and SE Light Rail	Transport for NSW			ALTRAC Light Rail
NSW	Sydney	Sydney Metro City and South East TSE Contract	TfNSW		Arcadis-MJA-PSM	John Holland/ CPB/ Ghella JV
NSW	Snowy Mtns	Snowy 2.0	Snowy Hydro	SMEC		
NSW	Illawarra	Maldon to Dombarton Rail Link	TfNSW	WSP		
NSW	Sydney	HarbourLink - Western Harbour Tunnel	RMS	WSP/ARUP		
NSW	Sydney	HarbourLink - Northern Beaches Link	RMS			
NSW	Sydney	F6 Extension Stage 1	RMS			
Qld	Brisbane	Bulimba Trunk Sewer Upgrade Stage 2	QUU			Abergeldie- Obyashi JV
Qld	Gold Coast	Gold Coast Seeway	Gold Coast Water		WSP	John Holland
Qld	Brisbane	Cross River Rail Authority	Cross River Rail Delivery	ARUP		
Qld	Toowoomba	Toowoomba Rail Tunnels	Dept Transport & Main Roads	SMEC	WSP	
Qld	Toowoomba	Inland Rail Kagaru to Gowrie PPP	ARTC	ARUP/SMEC	Aurecon/AECOM (Reference design)	
SA	Adelaide	Adelaide Bus Tunnel	DTIE		KBR	McConnell Dowell
Vic	Melbourne	Kalkallo Main Sewer	Yarra Valley Water	Aurecon (Project Manager)	Jacobs	Abergeldie
Vic	Melbourne	Melbourne Metro Tunnel and Stations PPP	MMRA	Aurecon Jacobs Mott MacDonald	ARUP/Arcadis/WSP	Cross Yarra Partnership comprising Lendlease, John Holland, Bouygues and Capella Capital.
Vic	Melbourne	West Gate Tunnel	Transurban	AECOM	Aurecon/Jacobs	John Holland/CPB Contractors JV
Vic	Melbourne	North East Link	VicRoads			
Vic	Melbourne	Epping Main Sewer	Yarra Valley Water			John Holland
WA	Perth	Forrestfield-Airport Link Project	Public Transport Authority	Various	GHD, Geodata	Salini-Impregilo-NRW JV
NZ	Auckland	City Rail Link	Auckland Transport	Aurecon-Mott MacDonald		Downer NZ and Soletanche JV McConnell Dowll and Hawkins JV
NZ	Auckland	Central Interceptor Project	WaterCare	Jacobs/MJA/AECOM		
NZ	Wellington	Wellington Northern Corridor	NZ Transport Agency		AECOM, Parsons Brinckerhoff and Beca	
NZ	Tauranga	Tauranga Tunnel	Local Govt			

Prospects

Scope of work	Current status
Spanning 9 km, NorthConnex will be the longest road tunnel project in Australia. Cost $3B	Awarded to Lend Lease Bouygues JV. Under construction for completion in 2019
Includes twin 3-lane, 5 km long tunnels from Ashfield to Strathfield	Contract awarded June 2015 for completion in 2019
Provision of additional four new lanes in a driven tunnel next to the existing the M5 East tunnel	Contract awarded in Nov 2015. Under construction for completion in 2019
Twin 8.5km road tunnels linking M4 East and M5 East Duplication and major undergound interchange at Rozelle	Contract awarded June 2018. Under construction for completion in 2023
Underground interchange linking the M4-M5 Link to Anzac Bridge, Iron Cove Link and future Western Harbour Tunnel	Tender closed September 2018.
Proposed cut and cover tunnels beneath Surry Hills and through under Anzac Parade through Moore Park	Under construction
Underground rail Link from Chatswood to Sydnenham via Central Station	Contract awarded June 2017. Under construction for completion in 2021.
2,000 MW pumped storage hydro scheme	Tenders in preparation
4 km single line rail tunnel forms part of 20 km rail link to Port Kembla	Registrations of Interest closed in April 2015 - On hold
Road tunnel linking WestConnex with North Sydney (Military Road)	Expected to come to market in second half of 2019
Road tunnel beneath Mosman connecting City with Northern Beaches	In planning
4 km of motorway tunnel from New M5 to Presidents Ave Kogarah	Tender expected Q2 2018
4.2 km of pipejack sewer tunnels	Under construction
Recycled water outfall pipeline including DN2100 pipejack, 1400 m long	Under construction
New north-south tunnel(s) with connections running from Dutton Park in the south to Victoria Park in the north and new underground stations at Boggo Raod, Woolloongabba, Albert Street and Roma Street.	Tender closes October 2018
Invert lowering for existing rail line to allow double stacked containers	Award to BMD
126 km rail link which includes three tunnels totalling 8.5 km in length	Tenders expected mid 2019
$160M extension of O-Bahn bus track through tunnel to Hackney Road in City North. 650m cut and cover tunnel	Under construction
Comprises 662m of DN1250 and 2,774m of DN1050, at depths varying between 4m and 15m. Nine manholes, ranging from 1.8m to 6m in diameter.	Contract awarded Feb 2017.
New rail tunnel between Footscray and South Yarra with new stations in North Melbourne, Parkville, CBD (2) and St Kilda Road.	Contract awarded in Dec 2017. Under construction
Proposed twin road tunnels (6km) and elevated road structures linking the Westgate Freeway at Williamstown Road with City Link	Contract awarded in Dec 2017. Under construction
Potential road tunnel from Greensborough to Bullen linking the Western Ring Road to the Eastern freeway	Expected to come to market in second half of 2019
2.4km of DN1800 pipejacked sewer	Contract awarded Sept 2017. Under construction.
7.1 km twin-bored, concrete-lined and 6.2 m internal diameter tunnels extending from Guildford Road in Bayswater to Dundas Road in Forrestfield. Three stations; Airport West station will be located underground in the Brearley Avenue road reserve, between Second Street and Dunseith Drive, close to the current Domestic Airport precinct	Under construction
A 3.5 km loop linking Britomart with the current western line. Three new underground stations at Aotea Square, Newton and K' Road. Britomart to Downtown involves tunneling under the historic Central Post Office building which is now home to Britomart station. On the other side of Downtown up to Wyndham St will be cut and cover tunnels	Ground breaking ceremony 2 June 2016
New sewer tunnel approximately 14 km in length from central Auckland to Mangere Wastewater Treatment Plant	Tender closed Q3 2018
Four lane expressway from Levin to Wellington Airport including duplication of Mt Victoria and Terrace tunnels	Site investigation underway
Three routes for a road tunnel through the Kaimai Ranges, linking Tauranga with the Waikato	Currently being investigated by the NZ Transport Agency

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