northwest
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Technical Paper Track Installation

ACAA 2020 Submission Stage 2

Sydney Metro Northwest - Operations, Trains & Systems (OTS) Contract

Northwest Rapid Transit Consortium

Comprising CPB Contractors; John Holland; MTR and UGL

MTR JOHN HOLLAND UGL CPB CONTRACTORS

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Contents

Project Overview

Sydney Metro Northwest is Australia's first fully automated railway.

The Northwest Rapid Transit (NRT) consortium successfully delivered the $3.7 billion Operations, Trains and Systems (OTS) contract, the largest of the three major delivery contracts for Sydney Metro Northwest.

The contract included:

- Constructing eight new railway stations and 4,000 commuter car parking spaces
- Constructing and operating the Sydney Metro Trains Facility for the stabling and maintenance of 22 metro trains
- Constructing two new services facilities
- Installing 23 kilometres of new track and rail systems
- Installing a new power supply between Willoughby and Chatswood for Sydney Metro
- Converting the existing 13 kilometres of railway and upgrading five stations between Epping and Chatswood to metro standard
- 15-year concession for operations and maintenance.

The OTS contract was awarded to NRT on 15 September 2014, which was the largest Public Private Partnership (PPP) in NSW at the time.

Through the PPP procurement model, NRT offered the NSW Government long-term value for money, from the five-year delivery phase, through to the ongoing 15-year operation and maintenance phase.

The partnership fostered strong relationships, shared goals and a collaborative approach. This created the foundation which resulted in the project opening on time.

This was achieved through NRT's strength of collective experience and ability to effectively manage cost and adapt programs to accommodate the challenges faced. This included client directed changes aligned with the broader metro strategy, the early handover of interfacing packages from the tunnelling contractor and balancing a revised handover strategy from the viaduct contractor, while still maintaining NRT's commitments.

The result - Sydney Metro Northwest project was successfully delivered on time and $1 billion under budget.

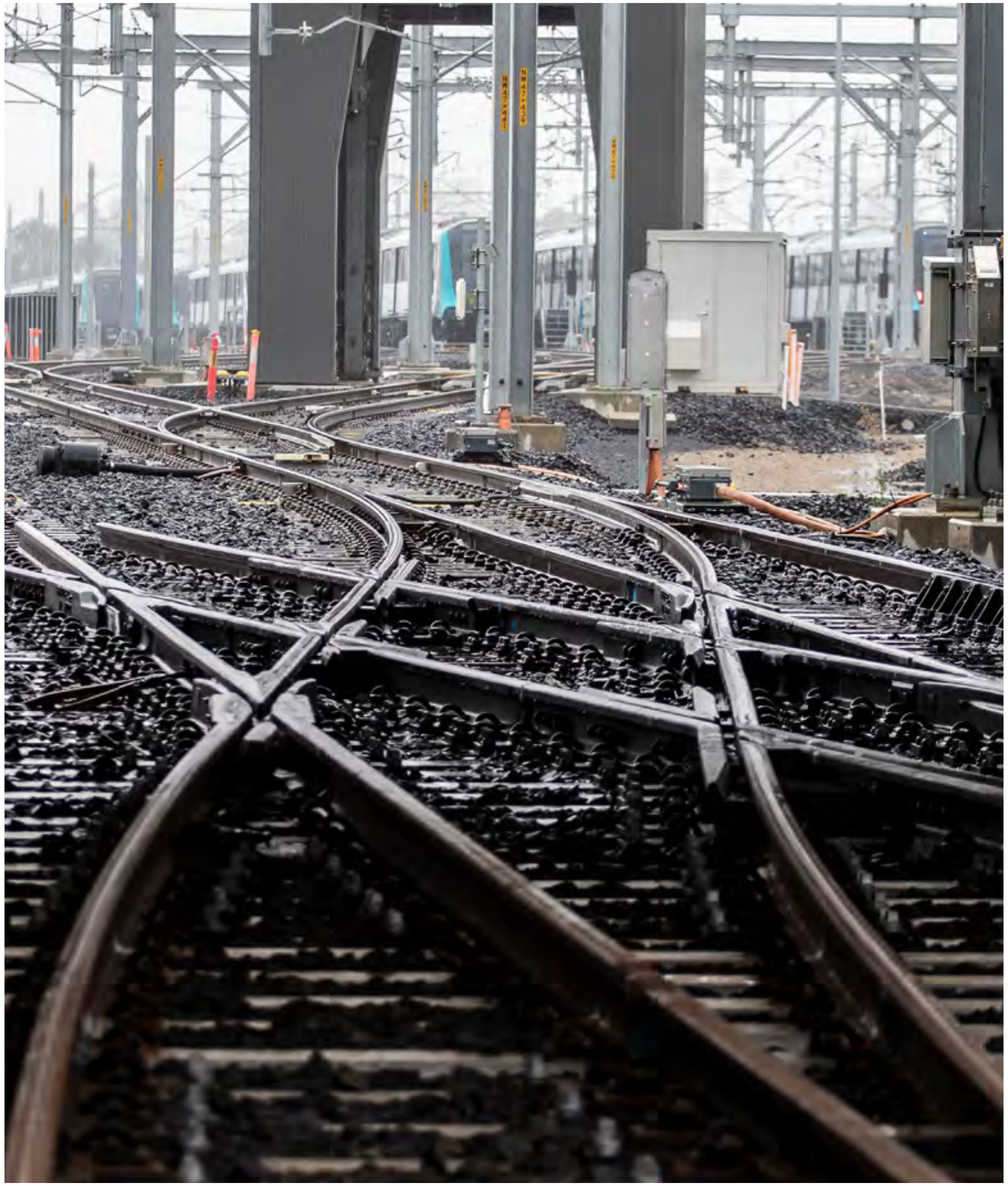
Project Scope – Track installation

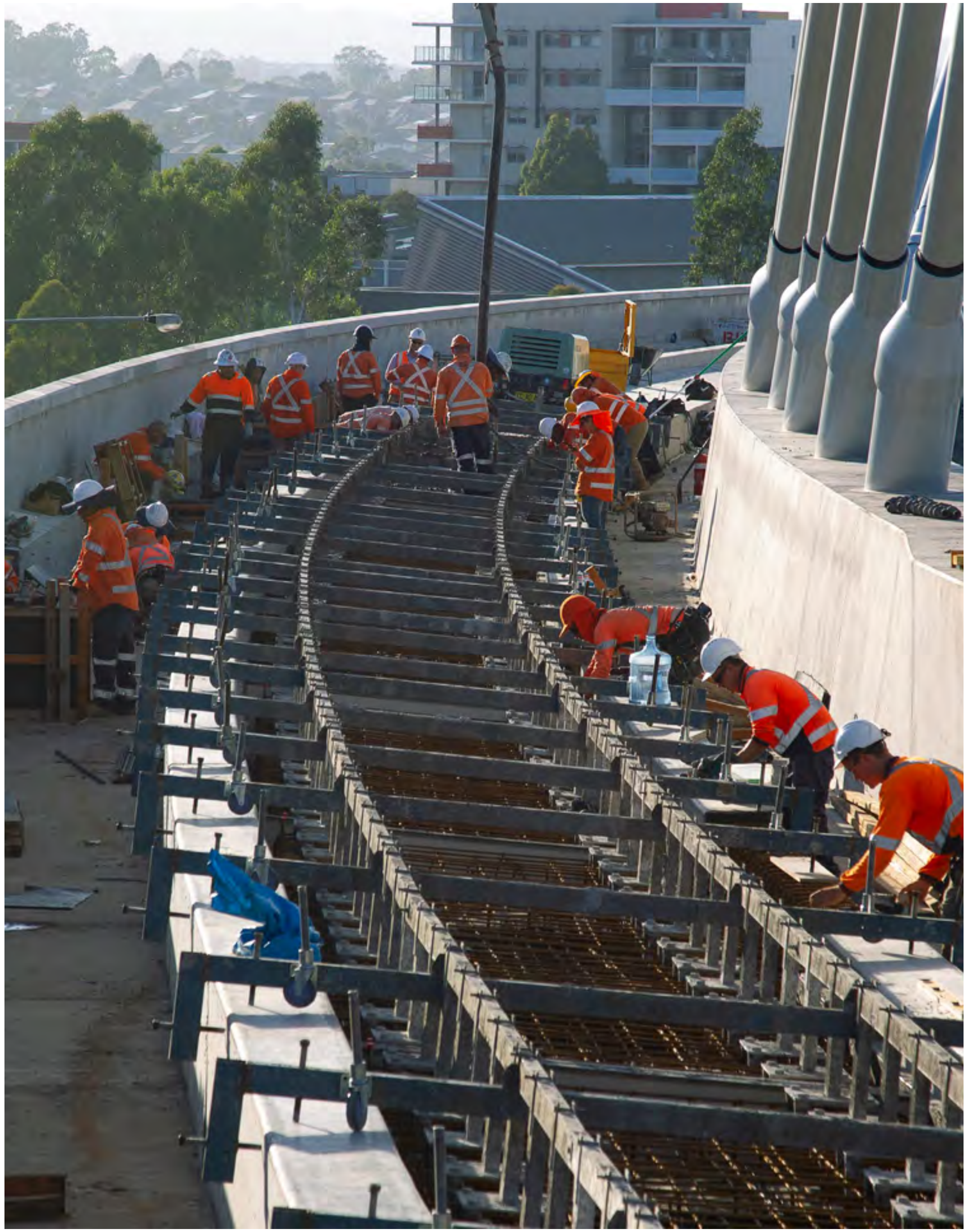
As part of Sydney Metro Northwest, 23 kilometres of new track (46 kilometres of up and down lines) and upgrading 13 kilometres of existing track to metro standard was delivered in four packages. This included the Sydney Metro Trains Facility (SMTF); viaduct; tunnel and connecting these greenfield tracks to the existing Epping to Chatswood rail line (ECRL).

Sydney Metro Trains Facility

Metro train maintenance, inspections, repairs, wheel maintenance and train washing is undertaken at Sydney Metro Trains Facility (SMTF). Trains are also stabled at SMTF every night and to facilitate the maintenance of trains, there are four different track types at SMTF – ballasted track, embedded rail, rail on pedestals, and direct fix track. The scope of track work undertaken between SMTF and Tallawong Station included the installation of the following:

- 9 km of ballasted track
- 35 turnouts
- 1 diamond crossing
- 650m of embedded rail – Edilon Corkelast method
- 400m track on concrete pedestals
- 80m of direct fix track
- 23 buffer stops – fixed hydraulic and friction type
- 800 flash butt welds
- 650 aluminothermic welds
- Trackside signage





Viaduct

The 270m curved cable-stayed railway bridge over Windsor Road at Rouse Hill, is the first of its kind in Australia. The scope involved the construction of the track on the bridge and 8 kilometres of viaduct, otherwise known as the 'skytrain' and the at-grade ballasted track connections at both the Bella Vista and Tallawong Stations, detail as follows:

- 18.6km of derailment kerbs
- 9.3km of track slab
- 26,580 baseplates
- 2 expansion switches
- 3km of ballasted track
- 4 x 1 in 18.5 R800 Tangential Turnouts
- 1,045 flashbutt welds
- 265 aluminothermic welds

Tunnel

The twin 15 kilometres tunnels between Bella Vista Station and Epping Services Facility were constructed by the previous contractor. Fitting out the tunnels included the installation of drainage before laying the invert slab to create a flat surface that the track could be laid on. Works also included:

- Staged construction of two tunnel track form systems, Type 2 and Type 3 Floating Slab Track (FST)
- Installation of 27,000m of track form
- Placement of 33,000m^3 of concrete requiring 6,600 concrete truck deliveries
- Installation of 190 FST sections over 3,250m of track
- Placement of 3,060m^3 of concrete for Type 3 FST
- 70,000m^3 of concrete tunnel invert slab
- Fixing 4 tonnes of steel reinforcement per 17.5m
- Length of track for Type FST, totalling 760 tonnes of steel
- Installation of 6,400m of Getzner matting below the Type 3 FST
- Profile grinding 27km of track

ECRL

Upon the successful completion of the greenfield works from Rouse Hill to Epping the challenge for the team was to connect the new greenfield tracks to the existing Epping to Chatswood Rail Line (ECRL), which became part of Sydney Metro Northwest. The new driverless trains terminate at Chatswood and then return to Rouse Hill. The ECRL tracks which became part of Sydney Metro Northwest were segregated from the Sydney Trains network at Chatswood and Epping over a series of weekend possessions. The scope can be summarised as follows:

- 2 new track slab turnouts EPP 12 and 22 at Epping Stub Tunnel, connecting the greenfield Sydney Metro to ECRL;
- 240m of track slab, connecting Sydney Metro to ECRL;
- 2 new track slab catchpoints EPP 13 and 23;
- Straight rail of 84, 85 and 86 pts at Chatswood, removal of Chatswood Turnback and drivers' walkway, and associated reconditioning and drainage modifications;
- Installation of two 200m Turnback Sidings at Chatswood;
- Straight rail of 92, 93, 95 and 96pts in Chatswood RES, special plates required for straight railing track slab turnouts;
- Removal and straight rail of 111pts at Epping; and
- Removal of 60 GIJs throughout the ECRL tunnel.

Program of works

All track work was completed over a 2 ½ year period with the first piece of rail installed at SMTF in June 2016, and the last piece of track work completed at the end of 2018 in preparation for train testing which commenced in early 2019.

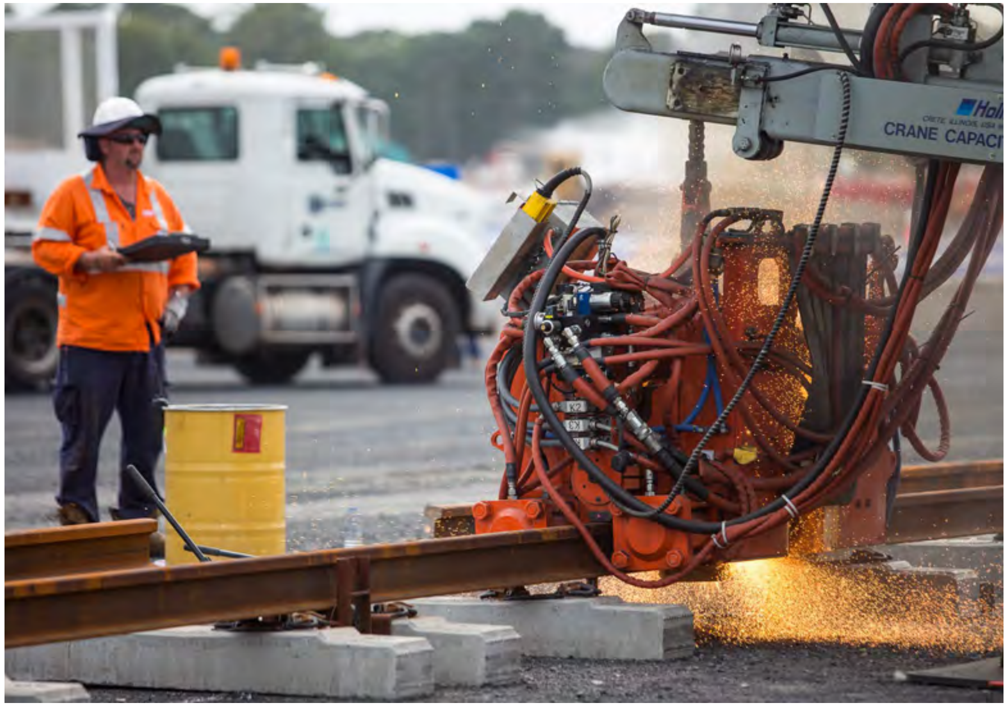
Sydney Metro Trains Facility

The team mobilised on the SMTF site in early 2016 with the first activity being flash butt welding 20m rails to form 120m lengths of rail known as rail strings.

Ballasted track was laid with both a 6 sleeper octopus and a bobcat. The track was top ballasted with hi rail dumpers and tamped with the 08 16 split head tamper which was lifted on and off the track with a crane.

All track work was completed at SMTF by September 2017 in readiness for high voltage, overhead wire and systems installation.

In January 2017, 20 turnouts and 2 kilometres of plain line track was constructed in 20 days. This was due to the relocation of a Sydney Water main delaying the initial start date requiring production to be accelerated for a successful outcome.



Viaduct

All work was completed over a 12 month period commencing in June 2017. The viaduct track construction was a production line of separate activities with derailment kerb, track slab, and rail installation all occurring at the same time in progressive locations.

In the early stages of design, the project team noted that a traditional top down methodology would not work as the track was being installed on a pre-cambered bridge that was constantly moving throughout the day due to temperature change and also after loading with concrete pours. As a result, a sequence was developed that allowed for bridge loading prior to the installation of track. This resulted in NRT constructing all concrete related elements first, casting voids for rail fasteners in the track slab, and installing the rail, plates and grout pads last to ensure the track was installed to the correct height and alignment, relative to both track design and also relative to the top of derailment kerb level.

Works commenced in June 2017 on Seconds Ponds Creek Bridge where the team undertook steel fixing for the derailment kerbs. At the same time flash butt welding commenced where 20m lengths of rail were welded into 120m lengths. Track slab commenced once the derailment kerb works were progressed sufficiently, followed by track installation.

On average, 312m of derailment kerbs, 80m of track slab and 120m of rail installation were completed every day. 50T of derailment kerb and 25T of track slab reinforcement was installed and tied each day.

A project record of 80 flashbutt welds was achieved in a single 10 hour shift.

Tunnel

Fit out of the tunnels commenced in April 2016 with the first activity being the installation of drainage before laying the invert slab to create a flat surface that the track could be laid on.

An onsite batch plant was used to feed the concrete paver machine which made its way through each tunnel laying more than 70,000m^3 of concrete which assisted in creating the flat surface.

Two large moveable scaffolds, known as gantries, also worked simultaneously after the invert had cured. These two gantries, were both 14 metres long and weighed 15 tonnes each and were mounted with six drills. More than 80,000 holes were drilled, throughout the 30 kilometres of tunnel network for services, walkways and overhead wiring.

The two moveable gantries drilled up to 42 holes over a 10 metre length of tunnel with a productivity rate of approximately 100 metres per day for each gantry.

In a coordinated process, the track team then loaded sleepers and fasteners onto the multi service vehicle to carry into the tunnels. The sleepers were then lifted into position exactly 700mm apart.

Once this was completed the rail was lifted onto the sleepers and manually clipped into place.

The Castle Hill cross over cavern construction commenced in August 2017 after the original design was revised. The original design included a mixture of in-situ concrete and precast concrete panels before it was decided that a structural steel plenum and fibre cement sheeting would be used.

The 55 cross passages were also fitted out with required systems providing safe egress between the two tunnels, along with 30 kilometres of walkway installed along the tunnel wall.

The installation of track within the tunnels was completed in a coordinated approach with multiple work groups in a limited space and a high level of interaction between the project station box entrances. Prior to concrete works taking place, a designated team had to flash butt weld rail.

Site coordination ensured the correct material was distributed to the nominated areas. At peak, the construction team installed 240m of plain line track during one shift, with the largest concrete pour over a 140m length.

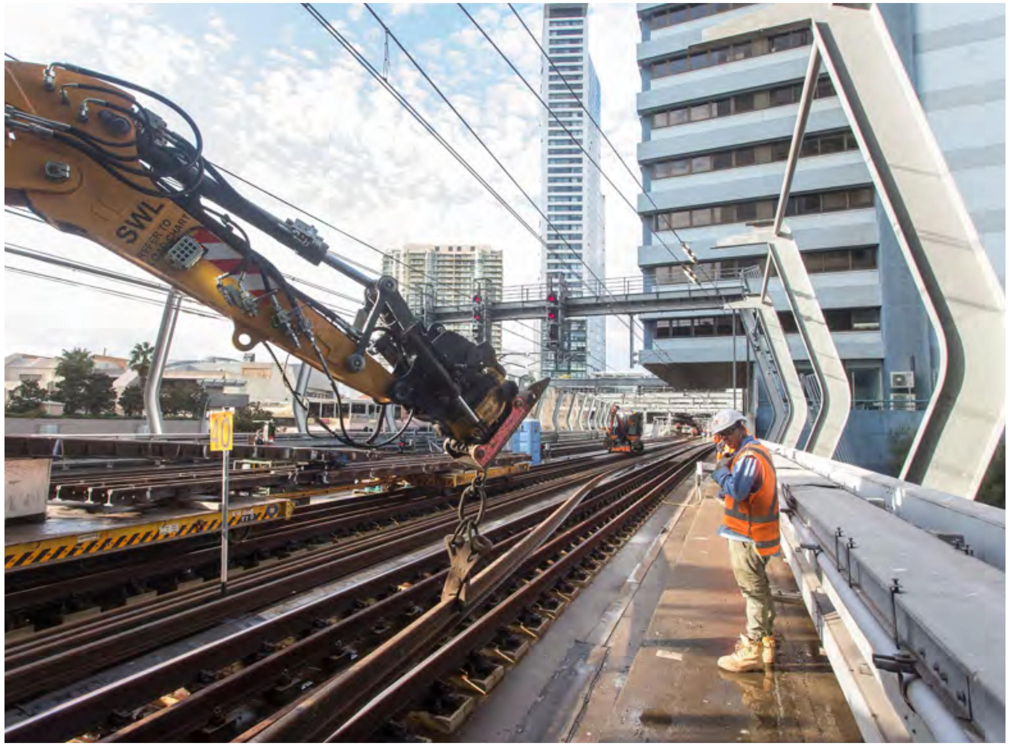
ECRL

A central component of the project was the conversion of the Epping to Chatswood Rail Line (ECRL) to metro standard during a major shutdown of the line and a number of critical rail possessions at Epping and Chatswood. The successful completion of this work was considered a key project risk by the client and other stakeholders. The shutdown commenced on 30 September 2018, following years of meticulous planning and preparation.

The conversion works included the removal of existing track connections at Epping and Chatswood and modifications south of Chatswood to achieve operational segregation from the Sydney Trains network.

New cable routes were provided to accommodate the metro services and signalling systems and modifications were made to existing systems including electrical, signalling, communications, fire and life safety, mechanical and fire systems and the traction power supply. The Chatswood north substation was segregated from the Sydney Trains network, for the future operation of the metro.

The removal of the stub tunnel bulkheads at Epping allowed the new tunnels to be connected to the existing ones and the completion of the track and OHW works in early November 2018 connected the track all the way from the buffer stops at SMTF to the buffer stops at Chatswood. The track segregation work was completed during a series of rail possessions, with every possession during the shutdown going to plan enabling all scheduled work to be completed each time. The final segregation works at Chatswood were completed in the first weekend of November 2018 which provided full segregation from the Sydney Trains network.



Accuracy to Design, Delivery and Survey

Sydney Metro Trains Facility

Embedded rail and track on pedestals were installed to an average accuracy of +/- 1mm vertical and horizontal alignment.

Ballasted track was installed to an average accuracy of +/- 3mm horizontal alignment and +/-3mm vertical alignment.

The ballasted track through the platform was installed to an accuracy of +/-2mm horizontal alignment, +/- 2mm vertical alignment, and +/-2mm super elevation. Due to the tight tolerances at platforms to comply with accessibility requirements there was no room for error and the tamping team rose to the challenge, delivering to the project tolerances for track at platforms.

Turnouts were all installed within project tolerances – gauge +/-2mm at switch tip and crossings; and kilometrage of points and crossings installed +/-10mm of design.

Welding alignment tolerances were achieved - .3mm maximum peak, 0mm dip and .5mm alignment in accordance with AS 1085.2 – AT1.

Viaduct

- Derailment kerbs were constructed to a tolerance of +5mm/-15mm for height and +/-10mm alignment
- Track slab was constructed to a tolerance of +/-10mm for height and alignment
- Track was constructed to a tolerance was +/-5mm for height and +/-8mm for alignment
- The top of rail level relative to top of kerb tolerance was +10/-20mm
- All special track work including the 4 turnouts and 2 expansion switches were installed within project tolerances – gauge +/-2mm at switch tip and crossings; and kilometrage of points and crossings installed +/-10mm of design
- All welding alignment tolerances were achieved – 0.3mm maximum peak, 0mm dip and 0.5mm alignment in accordance with AS 1085.2 – AT1.

Tunnel

The installation of 27 kilometres of tunnel track form for Sydney Metro Northwest was successfully completed by mid-February 2018. A total of 949 construction worklots were created and linked to 494 hold and witness points raised and closed out by the relevant designers. As built design review for the track alignment throughout the tunnel and at new station platforms was accepted by the designer and the track handed over to the train testing team in July 2018.

Tolerances achieved within the tunnel include:

- Track Alignment - +/- 8mm
- Track gauge - +3/-2mm
- Type I, II and II track slab - +/- 25mm

ECRL

Tolerances achieved on the ECRL conversion works include:

- Track Alignment - +/- 8mm
- Track Height - +/- 20mm
- Track gauge - +3/-2mm
- Concrete finished height - +0/-5mm

Complexity, Difficulty and Optimisation of the Construction Task

Sydney Metro Trains Facility

To mitigate the risk of stray current affecting concrete pedestals, a design was developed to electrically isolate the pedestals from the rail. HDPE conduits were cast in the concrete pedestals and then threaded rods were set into the conduits with megapoxy. A megapoxy pad was poured between concrete pedestal and HDPE pad. The team designed and manufactured rollers for constructing rail on pedestals which had a dual role. Firstly, the rollers and baseplates were used as formwork to cast threaded rods into pre-cast voids in pedestals and then later used to facilitate skiing rail into the Maintenance Building which was 210m long.

During a busy 6 week period over the summer of 2016/17, 2km of plain line track and 20 turnouts were built, tamped and welded during hot summer weather with temperatures up to 45 degC. This allowed the project to achieve an important handover date.

Viaduct

Building track to a tight tolerance on Australia's first curved cable-stayed bridge that moved up and down throughout the day was a challenge. As the bridge heated up through the day the level would rise approximately 10mm in the middle of each 40m span. This impacted on the derailment kerb and track construction.

To mitigate the effect of bridge movement, all derailment kerb survey set out was completed at night and marked on the bridge deck. As construction continued throughout the day, the team referenced heights on the deck and set the derailment kerb height to the levels set out at night when the bridge was in a neutral temperature and was not moving.

The same principle was applied to setting the rail line and level. The team poured grout pads in a 1 in 3 pattern at night, thus setting rail level when the bridge was not moving. The grout pads in between were then poured in the day shift, allowing for the installation of 120m of track grout pads per day. Megapoxy 206 Ultra was used to ensure the grout pads installed at night were set prior to the heat of the day.

Three purpose built systems were also introduced:

An 80m long formwork gantry for derailment kerbs: A specialist formwork gantry was developed to allow all four derailment kerbs to be poured at once on a face. Final design of the system allowed for minimal daily adjustment, which was necessary as time frames between pours did not allow for major adjustment.

The systems were 80m long, which allowed NRT to pour 312m of derailment kerb per day. The gantries were dragged along the bridge on steel wheels every morning. Then final adjustments were made for an afternoon pour.

Void form jigs for the track slab: A specialist hanger type system was manufactured that spanned across the derailment kerbs and hung cone shaped moulds in the track slab to provide a void for later installation of screw spike ferrules. The system was made of both steel and aluminium pieces to ensure strength yet flexibility around curves. The system was moved along the derailment kerbs every day on wheels and the alignment was adjusted for the following pour. This system was used in lieu of the traditional methodology of coring the track slab when installing direct fixed track.

Track top down equipment: Specialist top down equipment was manufactured to facilitate rail installation on the viaduct that included iron horses, push pulls, grout formwork and a roller system for moving rails over a 4km distance from the flashbutt welding site. Iron horses were positioned underneath the foot of the rail to lift the rail to the designed height while also holding gauge.

These were designed and manufactured by NRT and weighted 19kg each which is less than 1/3 the weight of traditional iron horses. Push pulls with rail moulded fittings were positioned between rail and derailment kerbs to align the track.

Specialist grout forms were manufactured to sit flush around the Delkor Alt 1 baseplates and sit level on the concrete track slab, a special seal was used at the bottom of the grout form work to stop megapoxy from leaking.

A roller system was developed to allow for multiple lengths of rail to be dragged or 'skied' onto the viaduct, without damaging any concrete surfaces.

Rollers were placed in the four foot and spaced every 10m to 15m. Rail was then dragged onto the viaduct a hi rail excavator.

Tunnel

The design of the tunnel track form system was required to meet challenging sustainability and performance criteria, which included addressing both noise and vibration requirements. As well as the Type 3 FST design being tuned to achieve the noise and vibration attenuation levels required, the system had to be relatively easy to install in confined spaces and incorporate the necessary electrical isolation requirements. Other technical challenges such as track drainage interfaces and jacking pockets also had to be dealt with. The design team was able to overcome these through design workshops and dialogue with the Operator, MTS, as off-the-shelf track form solutions could not be relied on as they did not comply with the project requirements.

Several challenges were overcome with the installation of Type 2 and Type 3 FST. During the twelve-month installation period, material handling and the movement of plant and machinery within the confines of a six-metre diameter tunnel required coordination with multiple work sites. In some cases, the travel distance from the entry point to the FST location was approximately two kilometres. Strategic placement of material and appropriate plant and machinery to suit the changing work environment ensured the tight construction program was achieved.

The enhanced track form design and high-quality construction installation of the Type 2 and Type 3 FST led to a successful project outcome. The minimisation of noise disruption to customers and residents within close proximity to the tunnel has been achieved through noise and vibration acceptance testing within the tunnel and achieving the Ministers Condition of Approval (MCoA) for sensitive receivers.

A small prototype was also developed to assist with upskilling the workforce, supervisors and suppliers in track form construction. This provided an opportunity to educate the team to ensure a durable track form was delivered as laying track within 15 kilometre twin tunnels is not a common occurrence within Australia.

ECRL

Delivery of 855m^3 of concrete into the ECRL tunnel presented a challenge, however was overcome by implementing the following:

Concrete Delivery Methodology

Investigating concrete pump locations was an area of concern on the project as site access was restricted by a freight rail viaduct at Epping. To suit site conditions and reduce the potential safety hazard of breaching live adjacent rail traffic, a gooseneck pump stand was developed to pump concrete into the concrete shuttle. The solution worked extremely well and was commended by the project safety team and client. The gooseneck eliminated the need for a boom pump and decreased the overall site footprint allowing other work groups access and also delivered a cost saving.

Voids underneath pads

All track slabs constructed in ECRL were installed using the top down method, with voids underneath HDPE pads being a key focus. When placing concrete in track slab it is critical that the vibration and concrete discharge speed is managed.

It was concluded from the trial slab that a defined concrete placement methodology was the most reliable way to manage voids. Through trial and error, it was noted that voids were minimised when concrete head was built up on the high side of the plate/pad and pushed across the pad by vibration. It was noted that trowelling a channel parallel to the rail on the low side of the plate encouraged the concrete to move as it created a space for it to flow to.

This method was used while installing turnouts and catchpoints. Concrete was pumped into the 4 foot and pushed to the outside edges using shovels and rakes. Once the concrete built up high enough, the team would vibrate it across the pad, from the high side to the low side. By controlling the speed at which concrete is pumped and placed, and educating the concreters with the importance of getting it right, voids can be eliminated underneath the HDPE Pads. It is important to note that all track slab pours in the ECRL Stub Tunnel has pads with void less than 25%, which is less than the allowable recommendation of 30% suggested by Delkor.

Key areas of innovation included:

Straight railing 4 track slab crossovers

The straight railing of the crossovers in Chatswood RES presented a challenge. In order to segregate the Metro tracks (formerly ECRL) from the North Shore Line, special plates were manufactured. Each plate was unique with the plates designed to bolt onto the Delkor eggs and the lugs designed to suit the new straight rail alignment and 1:20 rail cant. As the rail cant orientates the rail 7.3mm, the lugs were designed to take this into account. Critical survey works were undertaken to review the current track position and build a model to build the new special plates.

Concrete Turnout Installation

The two turnouts and catchpoints in Epping Stub Tunnel were installed using PEM LEMs. This was the first time PEM LEMS were used to install turnouts in a tunnel in Australia. Pre-building the turnouts was critical to achieving the programme. The turnouts were designed to be transported with PEM LEMs, the design comprising 1 in 4 bearers and Delkor eggs. Once the turnouts were built, the team proceeded with steel fixing in and around the bearers. The prebuild allowed the team to confirm track geometry, as well as reinforcement tolerances and starter bar lap lengths prior to bringing the turnouts into the tunnel.

Concrete shuttle for Track Slab

To minimise the concrete pumping lengths and to take advantage of the existing siding access into ECRL, a concrete shuttle was developed by the track team. The shuttle was mounted on a trailer and towed by a hi-rail machine. By having the machine on rail, it made the travel time extremely quick and simple. The dual access to the shuttle’s agitator was also another strong design feature as it allowed the team to ensure the agitator was always full before letting it travel into the tunnel.

Track top down equipment – ponies & covers

After several months of research and development to design and manufacture bespoke ironhorse for the Sydney Metro Northwest Viaduct, the team revised the design for the Epping Stub Tunnel turnouts and catchpoints. These ponies supported 1 rail only and the 1:4 bearers held gauge. “Ponies” were designed and manufactured to hold the track on design line and level prior to pouring concrete in our top down methodology. Special ponies were also designed to support the crossing due to its wider footprint.

Concrete Bearer design

The design of the turnouts and catchpoints called for 1 in 4 bearers to be cast into the concrete track slab. This opened an opportunity for a new design to be developed with Rocla, a trowelled pattern on the soffit of the bearer and tapered edges ensured the bearer would bind to the concrete in the track slab.

Works Train

A key innovation during the conversion was to utilise an 800 metre long (30 wagon) work train in the ECRL tunnels. This brought in all the materials and equipment required for the underground station works and took away all of the surplus materials removed during the modifications.

The team successfully achieved all the scope required for the first train to run through the tunnel to Chatswood on 14 January 2019 to allow dynamic testing to start.

Digital Emergency Tracking

During the ECLR conversion works, an innovative digital emergency tracking system provided many functions, including:

- Identifying and locating personnel within the ECRL between the Epping hi-rail access point and the Wilson Street hi-rail access in Chatswood.
- Supplementing the nurse calls at Epping, Macquarie University, Macquarie Park and North Ryde Station, providing additional emergency notification systems
- Communicating via IP radios running on a standalone WiFi network using both fibre cables and Cat6 network cables.

The installation of CCTV cameras at hi-rail access points (Epping and Chatswood) and the three crossovers at Epping, between Macquarie University and Macquarie Park Station and Lady Game Service Facility, allowing the Possession Protection Officer (PPO) to track personnel and plant effectively. Through the successful implementation of this system, NRT won the Sydney Metro Six-monthly Health and Safety Award in July 2018 for demonstrating a strong focus on worker safety.

Conclusion

The successful delivery of the project relied on the co-operation and support from the client, project partners and key stakeholders. Critical to the success was the continuity of project teams and leadership personnel.

As mentioned within this paper several innovations were created and implemented throughout the project that can be applied on future projects, generating an ongoing legacy for the rail industry.