UNIVERSITY CHALLENGE
STUDYING UP ON SEATTLE’S UNIVERSITY LINK LIGHT RAIL PROJECT

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EVERGREEN LINE AWARDED JUMP START ON AUSTIN’S JOLLYVILLE AND OTHER NORTH AMERICAN NEWS

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CANADA’S BIG RIGS PAY OFF PLUS OTHER NEWS AND CAREER MOVES FROM THE NA TUNNEL INDUSTRY
TUNNELING IN SEATTLE is challenging. And that’s not just down to the region’s complex glacial geology. Client and contractor must also deal with the local press and public perceptions of tunneling – vitally important if you need to secure funding for subsequent phases of work. For owner Sound Transit, the construction of the University Link (U-Link), the latest leg of its Link Light Rail network, is a chance to demonstrate that it has learnt from the problems encountered on the previous Central Link phase. And with the tunneling contract for the next light rail extension, the Northgate Link, out for industry review, U-Link contractors will be hoping their achievements will hold them in good stead.

As the U-Link tunneling contracts draw to a close, NATJ spoke to some of the main players to find out how lessons learned on the Central Link have helped on University Link – and what lessons can be taken forward to future phases. Though there has been a lot less media publicity associated with the U-Link compared to various other tunnel construction projects in the region, the designers and contractors on U-Link have faced some formidable challenges in the planning and execution of the project. For Joe Gildner, Sound Transit’s Executive Project Director on the U-Link, the biggest challenge was the unavoidable element of the unknown. “On any tunneling
The challenge is usually how well the nature of the soils are going to play out and how well the production is going to be for the contractors,” he says. “On this job, although we feel the design team did an excellent job in putting together a good GBR (Geotechnical Baseline Report), we had three TBMs and 21 cross passages to mine using SEM. And until the machines show up, you cannot be sure.”

Running for 3.15-miles (5km) between Downtown Seattle and the University of Washington down to Capitol Hill, substantial completion was 11 months late on top of 70 days of agreed time. The East Link tunneling work started in 2010, and the machines showed up in April 2012. Herrenknecht EPBMs to construct the 2-mile (3km) long tunnels from Husky Stadium at the University of Washington down to Capitol Hill for contract U220. For contract U220, Herrenknecht manufactures the EPBMs. The tunneling work split into two contracts, U220 and U230 (see Figure 1). Let under design-bid-build contracts, the North Transit Partners (NTP) JV, consisting of Jacobs Associates, HNTB Corp and Earthtech, with 26 subconsultants, designed the tunnels and stations to 100%.

Both U-Link tunneling contracts involved retaining works for the station boxes, with JCM excavating the whole of Capitol Hill, and TFK excavating launch shafts at the Southern end of the University of Washington Station. “For us the focus was coming off Beacon Hill,” says Gildner. “We wanted to have tunnel contractors who could stay focussed on the heavy civil underground construction activities and give ourselves the opportunity to look for another contractor to focus on the station activities.” This approach allowed Sound Transit to procure the tunneling contracts at competitive prices – it was reported at the time that the U220 contract had come in 22% below the Engineer’s Estimate. It also meant that Sound Transit could use a GCCM (General Contracting Construction Management) approach to the procurement of the station finishes. “GCCM gives us the ability to hire a contractor through a qualification process,” says Gildner. “And we can then get him in here to help with constructability and value engineering of the station layouts.” On the Northgate Link, this approach will be taken further as the station finishes will be only 60% designed, allowing for innovation and savings. Of course, more contracts mean more interfaces for the owner and construction manager: START JV (CH2M Hill and Jacobs Engineering) to manage and there have been issues. For example, TFK was due to take possession of the Northern end of JCM’s station box and some adjacent land in order to dismantle its two TBMs, which broke through into the box at the end of their runs. However, JCM were still tunnelling, using that area for their muck bin and having to hand it over would have caused them serious logistical headaches. A solution was found that suited everyone, with TFK’s two machines waiting patiently for four months to be dismantled. “TFK, JCM and Sound Transit came together and worked through the necessary interface issues,” says Gildner. “I am real proud of the way all three parties stepped up.”

While the University Link tunneling work was split into two contracts, the Northgate Extension will be let in a single contract, estimated between $500 and $540 million.
incorporating the running tunnels, 23 cross passages, two underground cut-and-cover stations and a portal at the north end.

“We have even smaller job sites on the Northgate Link extension than we’ve had to work with on University Link,” says Sound Transit spokesman, Bruce Gray. “Based on an extensive value engineering process, we arrived at the single tunneling contract approach to avoid interface issues and hopefully save on overall construction costs with more efficient equipment and overhead use.”

No chance of voids

One of the biggest lessons that Sound Transit learned on the Central Link project related to over-excavation by the TBM as it was relaunched from the east end of the station. Eighteen months after tunnelling on the Beacon Hill section was complete, a local homeowner was surprised to find a 12in (300mm) hole in her flowerbed adjacent to the front porch, which – on closer inspection – proved to be the neck of a 23ft (7m) deep, by 25ft (7.6m) diameter, dome-shaped cavity within 3ft (1m) of the centerline of the 110ft (35m) deep NB tunnel. Subsequent investigations located further voids, which were filled with controlled density fill (see NATJ, June/July ’11, p14).

One of the measures employed by Sound Transit to guard against over-excavation on Beacon Hill was the use of muck scales on the conveyors. However, the contractor had experienced problems with them prior to the relaunch of the TBM from the station, so spikes in muck weight were written off as a malfunction of the equipment.

Speaking to the contractors from both U-Link contracts, it seems that problems with the muck scales still exist. Both found them to be less than reliable. “Scales can be accurate if the material going over the scales is consistent, for example in gravel quarries,” says Glen Frank, Project Manager for JCM. “When the material is consistent, you can calibrate the scale so that you are measuring very accurately. When ground is changing, one minute almost liquid, the next big chunks coming through, you will not get accurate results.”

TFK discovered that the scales could not weigh anything over 90lbs (40kg). So when big lumps of hard clay were travelling over the conveyor, the weights of muck recorded were strangely low. “We were sceptical that they were going to work,” says TFK Project Engineer Matt Burdick. “But at the end of the day, although they weren’t very useful in terms of providing discreet data points, they did provide a windsock. Over a period of time, over 150 rings, you develop a trend.”

For both contractors settlement control relied more on the real time monitoring of pressures, watching the EPB sensors between drives to make sure sufficient pressure was maintained – and grouting through the tail shield immediately. Frank explains: “When we apply pressure through the machine, we change the pore pressure up into formation. It depends on the permeability of the formation as to how much time it takes for that pore pressure to bleed off and come back to constant pressure. If, when you stop mining, the pressure in the plenum drops back down, you are applying enough pressure. If it does not, then you are not.”

For Gildner, it was important that both client and contractor were watching all the important areas: Muck weights, pressures and samples if required. “Both parties monitored the face pressures and the grout pressures continually in real time,” says Gildner. “There were metrics we required shift by shift so that both parties were keeping tabs on those.”

Any anomalies required action. “If we had two or three rings with higher muck scale weights and lower grout takes, we had to go back and proof grout,” says Burdick. “That did not happen very often. “If we noticed we had a high muck scale weight we would sit there and grout to pressure,” says Burdick. “But at the end of the day, although they weren’t very useful in terms of providing discreet data points, they did provide a windsock. Over a period of time, over 150 rings, you develop a trend.”

Another strategy employed by Sound Transit to ensure the smooth running of the U-Link contracts was to carry out a series of advanced works including securing some permits, demolition works at the station sites and diverting utilities. One of the most technically demanding advanced works contracts saw Condon-Johnson & Associates clearing a pathway under the I-5 highway, which lies above the path of both JCM’s drives. Condon-Johnson had to cut four holes through the retaining walls’ piles, install tie backs to help stabilize the walls, backfill with controlled density fill and install monitoring on the walls.

Workers celebrate the completion of the U230 drives between Capitol Hill and Pine Street in downtown Seattle.
Associates. “If you are going to do any coast,” says Peter Raleigh of Jacobs and services that go up and down the West important transport route for all the goods below the expressway. “The I-5 is an under the I-5 highway, at its closest just 14ft U230 was the section where the tunnels run both designers and constructors on contract to settlement.

JCM had to do a proving section to demonstrate that the overcut would not lead to settlement. We did some extra settlement monitoring and measurement,” says Frank. JCM’s Hitachi Zosen machine had an extended overcut, partially to limit wear on the cutter tools, but also to accommodate the dual component grouting system with its injection ports outside the machine’s shield. JCM had to do a proving section to demonstrate that the overcut would not lead to settlement.

But of all the challenges, the biggest for both designers and constructors on contract U230 was the section where the tunnels run under the I-5 highway, at its closest just 14ft (4m) below the expressway. “The I-5 is an important transport route for all the goods and services that go up and down the West coast,” says Peter Raleigh of Jacobs Associates. “If you are going to do any damage you would really be in trouble.” The answer to this challenge came in the specification for the TBM, says Raleigh. “You need a reasonable amount of control of the machine, it’s got to be properly equipped with proper instrumentation.”

“We had to prescribe that once the tunneling started, they had to stay at it continuously,” adds Gildner. In parallel with the TBM considerations came the requirement for instrumentation and measurement at the surface. There were reflective targets monitored by theodolites from a distance and horizontal inclinometers over each drive, although the latter did not always perform as expected, says Raleigh. For the tunnels, the stretch under the I-5 was a tough one too. They needed to add plenty of conditioner to the dense impermeable clay in order to process the muck. “Our screw conveyor and muck handling system did not react very well to clay that remoulded,” says Frank. However, under the highway, the contractor had to limit the amount of foam going in – since there were borings up to the surface through which the foam could have escaped. “We had two competing goals,” says Frank. “The operators wanted to make production – we all want to make production – but the engineering staff had another goal of making sure we did not cause any damage on the surface.”

They had already seen the results of foam squeezing up through a borehole on an earlier section. A slimy mixture of foam and silt had shot 40ft (12m) into the air, dirtying a tree and two parked cars. Fortunately, there were no people in the vicinity at the time. Slimy mud on the road would have been a hazard for drivers, but was something JCM was able to avoid. Some foam did make it to the surface, but thankfully emerged in a grassy embankment and ran down only onto the hard shoulder, which the contractor was able to clean during the usual night time closure of the highway.

“The contractor did a very good job on those two runs,” says Gildner. “And I was really pleased with the way the contractor, owner and DoT came together.”

The tunnels’ curves, the tightest being a 550ft (168m) radius, complicated the ring build. The contractor had to add a third segment design, on top of the up rings and down rings, which had twice the taper of the others. “We had to spend more time training the crews, to make sure we could build the rings so they butted up correctly to each other,” says Frank.

Both contracts used the same segments, cast by a Traylor Bros and Technopref joint venture using existing moulds that came from...
Through into the stub tunnel.

wrapped round its cutterhead as it broke individual strands, and with just a few however, says Frank, producing 2ft long preventing the machine from advancing. The machine out.”

that we could get bigger pieces of the tunnel from the activity and dust of the construction operation. The new solution had safety and cost on its side.

“We pretty much built it per plan,” says Frank. “We made the adit a little bit bigger, separating the ongoing operation in the Southbound tunnel, so running perpendicular to the ties, it might have been a different story.”

Having tackled the design issues around the connection at the Pine Street Stub Tunnel, NTP has made sure that they aren’t re-encountered in other locations things ran smoothly, in other locations things weren’t exactly as expected. It was water – or rather its position – which caused the biggest surprises. First, the contractor discovered as it excavated the Capitol Hill station box that excavation ended up taking seven months rather than the intended five. Thankfully, the problem was limited to one end of the box however, which meant ICM could pour concrete at the other end and start assembling the TBM.

Second, ongoing, differing site conditions claim relates to the construction of two of the five SEM cross passages, where the contractor clams ground conditions were more onerous than expected. “Two were designed to be dewatered but we ended up with three that needed to be dewatered,” says Frank. “The difference was in where the aquicludes were in relation to the aquifers.” Subconsultant Dr. Sauer Group designed the 21 cross passages for both contracts. “The notable thing about the design was that the location of the cross passages was chosen in order to minimize the adverse impact of the glacial soils, placing them in the more competent soils, rather than in the sand and gravels,” says Dr Sauer’s MD Juergen Lauböckler. So the final position of the cross passages was not fixed until the ground conditions had been inspected at that point, stopping the TBM to do so. The contract required these inspection stops which TFK performed with a camera mounted inside the TBM bulkhead. if the camera inspection determined conditions were safe, the excavation chamber hatch was opened and a soil sample was taken.

The LA Metro project.

One of the most complex areas of the U230 contract was where the two tunnels joined the existing Pine Street Stub Tunnel (PST), not least because the tunnel was in use throughout the works. NTP made extensive changes to the final design, which Sound Transit’s preliminary designer Parsons Brinckerhoff had proposed, and the fact that the contractor followed the new design with little adjustment is testament to its success.

The original design included two reception shafts, with the last stretches of both tunnels, around 100ft (30m) long, up to the retaining wall of the stub tunnel constructed using SGM. The difficulty in this area was the presence of sander piles and tie backs – temporary works from the Pine Street Stub Tunnel construction – together with other underground obstacles. Another challenge was that the tunnels had to break through the retaining wall at angles rather than straight on. This was partly due to an earlier change, which moved the station to Capitol Hill from First Hill – abandoned because it would have been a deep station in difficult ground, similar to Beacon Hill.

NTP’s reworked design saw extensive ground treatment of the area using jet grouting so that the TBMs could just tunnel right through. There was one reception shaft on the Northbound tunnel with a hand dug adit connecting to the Southbound tunnel, so that some parts of the machine could be retrieved at the end of the second Southbound run, leaving the TBMs shield in the ground. NTP also came up with the idea of a false wall inside the stub tunnel, separating the ongoing operation in the tunnel from the activity and dust of the construction operation. The new solution had safety and cost on its side.

“Rather than the bottom of the permeable ground being 15ft to 20ft below the bottom of the excavation, it was above the bottom of the excavation,” says Frank. The quickest solution was to put more dewatering wells in, but the excavation ended up taking seven months rather than the intended five. Thankfully, the problem was limited to one end of the box however, which meant ICM could pour concrete at the other end and start assembling the TBM.

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The design foresaw some cross passages in Category II ground. “There was an excavation class that prescribed probing and vacuum dewatering in combination with pre-support and pocket excavation to ensure the stability of the face and of the tunnel excavation itself,” says Laubbichler. “After an initial learning curve, and with guidance from Dr Sauer SEM field personnel, this was executed very well by both contractors.” Despite the technical issues on U230, these have not offered the biggest challenges to Frank and his team. The biggest lesson learned was about working with Sound Transit. Next time they would allow for more resources to deal with the high flow of information required from contractor to client. “The challenge that we felt we had was keeping our scope to just building the tunnels,” says Frank. “We felt like we were asked to provide an awful lot of consulting to the owner. Because it is so urban, there are multiple third parties and the owner, being a transit authority, wanted to communicate with all of them. Now we pretty much know how they are going to administer that next contract. We have a good feel for how much support we need to supply them in order for them to be able to take care of their interests and how much staff time and effort we need to be able to supply.”

Contract U220: University of Washington to Capitol Hill

Time was the biggest enemy for TFK on contract U220. Their site at the University of Washington end was basically borrowing land from the Husky Stadium’s car park, so the lease they had was as tight as it could be. “Having the construction site on the Husky Stadium doorstep was a real sacrifice for the University,” says Raleigh. “For the contractor it meant that they had to keep their site very clean, neat and tidy.”

The impact went far beyond good housekeeping, however. The really interesting result of the schedule was that TFK had to start mining cross-passages whilst it was still constructing the running tunnels. The solution devised has provided good lessons, says Burdick – on what works well, and what works less well. The first innovation saw TFK employ Halcrow to design an alternative propping system to the squirrel cages, which would traditionally be used. This involved temporary shotcrete on the tunnel lining, around the area where the segments for the cross passage were to be broken out.

This has worked well, but what Burdick calls “the 600lb gorilla in the room,” is how hard it will be to break this temporary shotcrete off. When NATI spoke to Burdick TFK was preparing to start the removal operation following the formal array of machines and tools, not knowing yet what would be most effective. “I have multiple concerns,” he says, among them safety, ease of operation, quality of final result and program. Assuming the removal operation is successful, this form of propping could be useful on future jobs, says Burdick. “Whether you used it would be a function of how many cross passages you have to do in the schedule,” he says. “We needed to have a lot of propping installed for a long period of time. For us it was cheaper to use shortcrete propping rather than steel because of the expense of fabricated steel. With shortcrete you are able to install it in around three and a half shifts. Steel takes twice that long, it’s very expensive and pretty dangerous.”

The second innovation for the cross passage construction was collapsible work decks which folded down onto a scarf car. These served as working platforms for mining of the passages, allowing the locomotive bringing segments to pass underneath. A mini-conveyor carried muck off the platforms to join the main conveyor.

“The biggest problem was that we were working up to five cross passages at some stage at any given time, behind the machine that was 1.5 miles ahead and still making 70ft a day,” says Burdick. “Work that required blocking the rail, such as work deck installation, had to be sequenced around the trains feeding the TBM or performed over the weekend during non-mining shifts. It was a huge co-ordination effort.”

There are things Burdick would do differently another time. “The actual excavation is difficult because until the machine stopped, the vast majority was done by hand which is ‘1800’s technology,” he says. “With a little bit of change to the design we would have been able to do more mechanically. It could be done.”

Gildner is appreciative of TFK’s methods for the cross passages. “It was very innovative on their part,” he says. “You have really got to take your hat off to them to be able to do those two major activities at the same time.”

When Raleigh was asked whether he would advocate constructing cross passages at the same time as running tunnels again, this was his response: “Contractors can make mistakes if they are doing something that is unconventional or uncomfortable. But you cannot always have harmony between schedule restraints and the use of standard methods.”

For Burdick, however, the biggest technical challenge was not the cross passage construction, but preparing for something that never happened. The highest expected pressure along the route was 6.2 bars, which meant that TFK’s machine and processes had to be able to cope with interventions to inspect the cutterhead or change tools.

The first hurdle was gaining the necessary compressed air working variations from the state. Laws relating to working at high pressure have not been updated for years, so special permissions are required to work above 3.5 bars. The Herrenknecht machine was also set up with a double manlock so that crews could work in rotation if necessary. And the contractor had a shuttle lock to ferry injured compressed air workers to the onsite medical lock for treatment or deliver divers from the surface under pressure, should...
significant difference in limiting grout leakage. And he advocates a clean ring build area to avoid getting dirt on the gaskets which impact on the seal achieved. "That's one of the things we need to work on, figuring out a better way of sealing the machine," says Raleigh. "There are developments underway in that area to come up with a differing type of sealing between the tail shield and the rings."

As an contrast 230, TFK are claiming differing ground conditions at certain cross-passage positions. Of the 16 they had to build, four were expected to be in Category II ground and require some dewatering. But TFK claims the ground was worse than expected at cross passage 17, requiring dewatering from the surface before completion, an operation which was not intended in the original design. Just one cross passage, 9, was relocated to better ground after the inspection via the TBM. One area which looked potentially tricky on the surface or got a huge blow in," says Burdick. With a team of spotters poised on the surface, the only evidence that anyone saw was a few bubbles rising to the surface, possibly condition or possibly gas from rotting vegetable matter at the bottom of the water course.

Apart from the interface issues where TFK had to wait to get into the Capitol Hill station boxes, there have been few contractual issues, says Burdick. "It is a $300 million job and we are waiting on the order of 2% or 3% change in contract value, which is pretty good."

**Looking ahead: Northgate Link**

There are many practices which Sound Transit is taking through from U-Link to Northgate Link. Though the owner is looking to new ways of procurement, for example using GCCM on the station fit out contracts, it prefers to stick to Design-Bid-Build for tunneling. "Together with the way we use GBPAs, Dispute Resolution Boards and Excrow documents, we feel very comfortable with Design-Bid-Build in tunnels," says Gildner. "This is mainly from the standpoint of our allocation of risk when it comes to heavy underground civil work."

Gildner believes that it is really important to invest sufficiently in a good GBP, drawing on the empirical data from all Seattle’s tunneling projects. "As we frame the nature of the hydrogeological conditions, we have to make sure that we are providing an adequate baseline and make sure the bidders feel comfortable with the way we have characterized the soils."

Sound Transit’s method of selecting the three-man Dispute Resolution Board jointly, rather than each party electing someone, works well for them, says Gildner. On U-Link, some differing site conditions claims had to go before the DRB, although others were accepted without it.

Another practice which Sound Transit will take forward is specifying the primary support system for SEM tunnels. On U-Link, there were two categories of primary support specified as a result of the hydrogeological conditions. To this the specification adds an additional ‘toolbox’ of supplementary items: "The SEM experts down at the heading might want to call for supplemental items," says Gildner. "We list all these out and pre-price them at unit prices. We think this is fair and reasonable."

There is one area where the specification might change. And that relates to the TBMs. The specification will call for a machine that can maintain active face pressure, as on U-Link, but Sound Transit has not decided yet whether it will insist on new machines as it has in the past. "We have been specifying new machines, based on risk assessment," says Gildner. "We recognize the importance of the hydraulics and these soils to tend to be abrasive. However, the agency has yet to take another look at specifying new versus used."

As for U-Link, there is still a long way to go before its opening in four years’ time. Gildner estimates that the project is around 60% complete. With tunneling work behind them, the risk register must be considerably shorter than it was. Both the crossings beneath the I-5 Highway and the Montlake Cut were "earmarked as high risk items" says Gildner. "I think we were a little bit less realistic," says Raleigh. "Or I should say that the ground is not as bad as we thought it was."

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