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SCL Gaining Strength

Silicon Valley progresses with its design-build first

In Silicon Valley, construction has started on the US's first-ever progressive design-build tunneling project. Kristina Smith spoke to the team to check on progress so far.

It is less than two months since design-build contractor Barnard-Bessac JV, with designer Arup, signed the $206m contract for Silicon Valley Clean Water's (SVCW's) Gravity Pipeline Project. But already work has begun on site, with specialist contractor Malcolm Drilling constructing the walls for the TBM launch shaft.

The swift start is down to the procurement method: progressive design-build, a first for tunneling in the US and one of the first in any sector. For an authority that had not used any form of design-build before, this seems like a bold move. But it was a necessary one says SVCW general manager Teresa Herrera.

"SVCW was following a design-bid-build procurement method. Two events occurred that re-directed that process and pointed us to consider an alternative delivery method," she says. The existing pipeline, coping with far greater flows and pressures than it had been built for, suffers regular failures and leaks.

Construction Management at Risk (CMAR) and fixed price design-build were also on the table, but it was progressive design-build that seemed the most appropriate. Progressive design-build involves a two-stage tender. First, the owner selects a design-build team to take the design to around two-thirds complete, in this case to 60 percent. Then for the second stage, the owner agrees to a price with the design-build team for completing the design and constructing the asset.

Herrera explains the decision: "Since this was SVCW's first design-build approach, staff sought more input to the design over less," she says. "We also wanted price certainty after the

Silicon Valley Clean Water's RESCU program

Since Silicon Valley Clean Water's wastewater pipeline was built over 45 years ago, there has been a huge growth in the population of the San Francisco Bay service area. Built as a gravity main, the pipe was modified to a force main to take around three times more flow and pressure than it was designed for.

The old reinforced concrete pipes can leak in places, due to a variety of factors. Joints have a tendency to move in the soft young bay mud in which they are located, quite close to the surface. In other instances, corrosion due to the salty soil and to the effluent within the pipe has weakened the concrete.

Hence the need for SVCW's $495m Regional Environmental Sewer Conveyance Upgrade (RESCU) program, formally known as the Conveyance System Improvement Project. Ten years in the planning, the program encompasses eleven projects, the largest of which are the Gravity Pipeline, Front of Plant and the Pump Station Improvements project, to upgrade the four pumping plants which will feed the new pipeline. All three of the RESCU program's major projects are being delivered under progressive design-build.

Shea-Parsons JV won the $122m Front of Plant contract. This includes the construction of the surge and splitter flow shaft which will also act as the retrieval shaft for the Gravity Pipeline's TBM, and a larger shaft to accommodate the Receiving Lift Station which will raise flows up for processing at the existing waste water treatment plant.

design was completed to the 60 percent level. Finally, we wanted to work with the 'best minds' around the table during Stage 1 which meant our staff, our Engineering Owner's Advisors – the original designer - our construction manager, and the design-builders who are the experts at designing and building this facility."

The big potential benefit of progressive design-build for the owner is that, by involving the contractor and its designer early, this method harnesses good ideas and ensures buildability. Since the owner is also involved in the design for longer, there should be operational and maintenance benefits.

The downside is that the cost isn't pinned down until later in the design process. However, there is the option to pull out at the beginning of the second stage, should it be impossible to agree on a price. And, as Herrera says: "the price certainty enables the agency to plan its financing needs with confidence."

Barnard-Bessac and Arup were appointed to carry out the first stage of the design back in October 2017, beating off competition from the two other tenderers Kiewit/McNally/Stantec and Obayashi/JayDee/McMillen Jacobs. Looking at the weightings in the RFP published in summer 2017, underlines how progressive design-build elevates competence over costs at the tender stage; fees account for just 15%. The rest of the marks are awarded for qualifications and experience, understanding the key challenges, project approach, innovative ideas and schedule and approach to pricing and lifecycle costs.

Urgent need

SVCW's Gravity Pipeline Project will replace an ageing pressurised waste water system which serves the cities of Belmont, Redwood City, and San Carlos, and the West Bay Sanitary District in California. The new 3.3mile (5.3km), 11ft (3.35m) inside diameter pipeline will run from Inner Bair Island south of San Carlos Airport to SVCW's existing wastewater treatment plant in Redwood City, collecting flows from surrounding areas. A second progressive design-build contract is providing major modifications to the treatment plant (see box, 14)

The Earth Pressure Balance (EPB) TBM, which Herrenknecht is currently building, will dig two legs, starting both times from the launch shaft, which is located at the junction of Shoreway Road and Redwood Shores Parkway (see map). The first, 5,200-ft (1.6km) section will extend to a recently-constructed 48-inch (1.2m) force main on Inner Bair Island. The second will head from the shaft down to the treatment plant.

"Launching from Inner Bair Island and doing one continuous tunnel was a very interesting option," says Mike Jaeger, project manager at Tanner Pacific, which is providing construction management services to SVCW. "Everyone liked it. But Bair Island is an environmentally sensitive area and to clear the environmental hurdles would have taken more time than we had available."

Built in the 1970s, the existing reinforced concrete pipeline was designed initially as a gravity main and then became a force main later to accommodate extra flow. The 48 and 54-inch (1.2 and 1.4m) pipes, jointed at 12 feet (3.7m) centres were laid in trenches in the soft and compressible young bay mud, which can experience large displacements during seismic events and due heavy rainfall or traffic. Consequently, the main has a tendency to move at the 12-foot on-center joints which can cause cracks and leaks..

SVCW considered many options before finally deciding that a TBM-constructed pipeline was the best solution. The EPBM will dig a 16 foot (4.9m) outside diameter tunnel which will then be lined with a 11-foot (3.4m) inside diameter fiberglass reinforced pipe.

One of the first tasks for the design-build team was to decide what sort of lining would give the best long-term result for SVCW. Ten possible solutions were narrowed down to three: a two-pass lining with the fibreglass reinforced polymer mortar pipe, tunnel segments with a cast-in HDPE lining or concrete with high-alkali aggregate and an additional sacrificial thickness.

"BBJV spent the first two months of the Stage 1 Services contract evaluating the various tunnel lining options along with SVCW to determine the most resilient design that would achieve a 100-year design life," says Jack Sucilsky, project manager for BBJV. "We looked at all the pros and cons, schedule, cost and life cycle costs."

Over its 100-year life, the pipeline must withstand attack from within and without. Internally, there will be hydrogen sulfide from the wastewater, externally the ground water is saline.

All the options were carefully assessed, with the final choice being the tried-and-tested approach. "The client was really highly concerned with making sure that the 100-year life is there, they really wanted to be convinced that the product was going to make it that long," explains Jaeger. "There were too many unknowns with newer products."

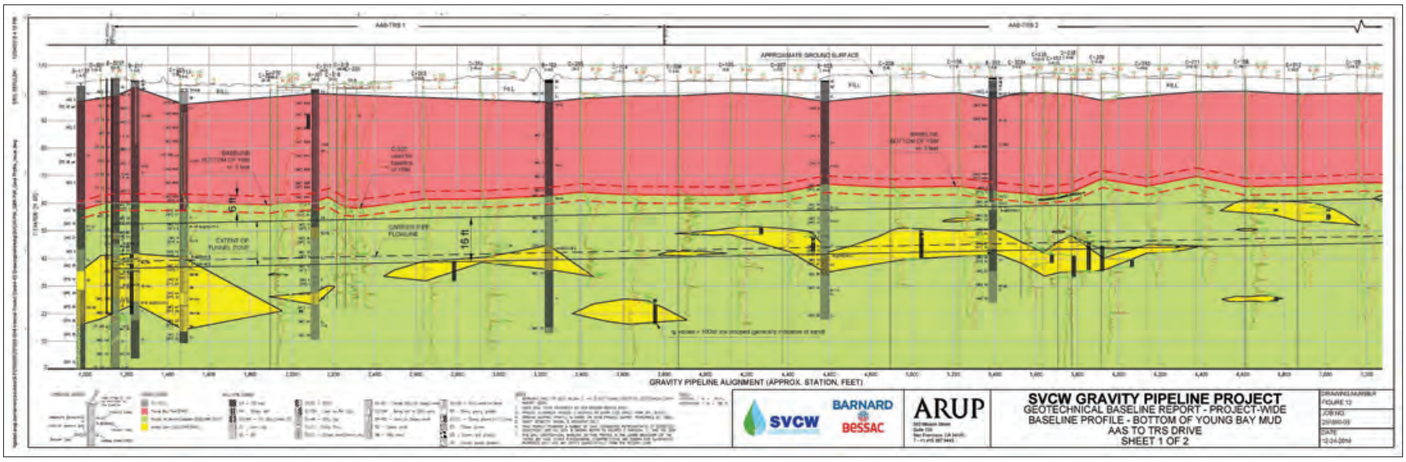
The contract's "very unique warranty bond requirements" means that the design-builder also needed to assure itself that the solution was robust, adds Sucilsky.

The concrete segments which will form the primary lining will be steel fibre-reinforced. Barnard-Bessac was negotiating the subcontract to supply these at the time of writing.

The pipeline design must also cope with seismic events. The requirement is for a two-level earthquake hazard design approach of 475-year and 2,475-year return periods and in accordance with AASHTO Seismic Methodology and FEMA Seismic Guidelines for Water Pipelines.

Arup's design had to look at short-term seismic resilience for structures such as the launch shafts and long-term resilience for the structural connections and FRPM pipe joints between the inlets and the tunnel, according to Luis Piek, Arup's tunnel design lead.

"The FRPM inner lining can take large amounts of deformation, which is another benefit of choosing that material,"



The tunnel runs largely in clay material, below the soft young bay mud. This cross section shows half of the longest drive, with sand lenses – likely to contain water - shown in yellow.

comments Glenn Strid, project engineer for Barnard-Bessac.

A relatively large diameter has been chosen for the gravity pipeline in order to equalise the flows, which vary from 2 mgd in the middle of the night during the dry season to 103 mgd, the flow projected for a 10-year rain event. "Although this is a wastewater system only, it is leaky and that means that during flood events, it does fill with water," explains Nik Sokol, design manager for Arup. "SVCW wanted to ensure a constant pumping rate to optimise operational and maintenance costs."

Getting the right baselines

The tunnel will run at a depth of between 35 and 65 feet (10 to 20m) below ground and should remain in alluvial and marine deposits, mainly sandy clay and clayey sand, for its entire length. The alignment has been chosen so that it doesn't stray into the young bay mud above it.

SVCW carried out an extensive site investigation before tendering, with bore holes or cone penetration test readings at roughly 250 feet (75m) centres along the route. BBJV and Arup augmented this later with further site investigation.

However, there may be some dips in the young bay mud, which the boreholes haven't coincided with. This was discovered to be the case near the water treatment plant, where the young bay mud dips from 40 feet (12m) below the surface to 90 feet (27m) below, requiring part of the structure to be moved to an area where the mud was shallower.

There will also be sand lenses which could contain water. "There is a lot of variation in the hydraulic conductivity of the sand lenses along the alignment," says Sokol.

"We looked at the deeper sand lenses as part of the shaft design. Our current understanding is that there is a hydraulic charge which could cause the base of the shaft to blow out when we dig down, were we not to introduce mitigation measures." Depressurization wells are currently planned as the mitigation measure.

The ground conditions meant that the choice of an EPB machine was an obvious one, says Bernard Catalano, technical manager for BBJV. Team members bring experience from EPBs in similar ground on The Bay Tunnel and in soft ground on the Central Subway project.

The decision on how to haul the muck out of the tunnel was not so cut and dried, says Sucilsky. The team had to choose between rail cars, which would attract less capital cost, and conveyors which were likely to give programme advantages, whilst considering how the sticky clay might impact on the system.

"With muck skips, cycle times become critical at the launch shaft. So even though the muck skip option carried a cheaper capital cost, BBJV felt that a continuous conveyor option gave us the opportunity to increase production rates which would offset the additional capital cost," says Sucilsky. "There were conversations between BBJV, the owner and the owner's advisers." H+E has won the contract to supply the conveyors.

Another long-running conversation regarded how to best design the TBM's cutter head to cope with the sticky clay. "We think we have managed that risk to the best of our ability during design," says Sucilsky. "We have designed the cutter head to have a maximum opening ratio of over 40 percent. And there are six injection points for foam in the cutter head."

BBJV has taken soil samples and is performing laboratory testing to work out how the muck will behave once it has been conditioned. "We encountered similar clay geology on a stretch of the Central Subway job," says Sucilsky. "Similarly, Bessac have had decades of experience tunneling in clay geology and BBJV is trying to manage that risk through design with our internal resources and the TBM supplier."

At the time of the initial tender, SVCW provided a geotechnical data report (GDR) only to the bidders. The Geotechnical Baseline Report (GBR), which is the tool used to measure how the ground differs from what was agreed contractually, was written by Arup, as part of the design-build team, during Stage 1 of the project.

"Overall, the GBR process went well," says Strid. "It could have been pretty controversial, but it really wasn't. There had been a lot of site investigation beforehand and we did extra investigation. Arup wrote it, and everyone commented on it."

The types of baselines to include was one of the elements that the review process was able to refine, says Sokol. One of the biggest criticisms contractors

The proximity to San Carlos Airport means that there are height restrictions at the launch and connection shafts. At the InnerBair Island Shaft shown in the photo, the limit is 53 feet (16.2m) above ground level.

level at GBRs generally is that the baselines included cannot be practically measured on site; this collaborative process has greatly reduced that problem.

Shaft challenges

From a technical perspective, one of the most interesting tasks for Arup's design engineers has been reaching the optimum design solutions for the shafts at Inner Bair Island and San Carlos, where existing flows will enter the new pipeline. Approximately two-thirds of the flow will enter the pipeline at Inner Bair Island, with the remainder entering about a third of the way down the pipeline at San Carlos.

"The incoming pipelines are fairly shallow but the tunnel is deep, so we have to drop the flows into the tunnel system in a controlled way," explains Peter Wilkie, Arup's hydraulics lead. "We don't want excessive velocities because of the wear it could cause as it hits the bottom of the tunnel."

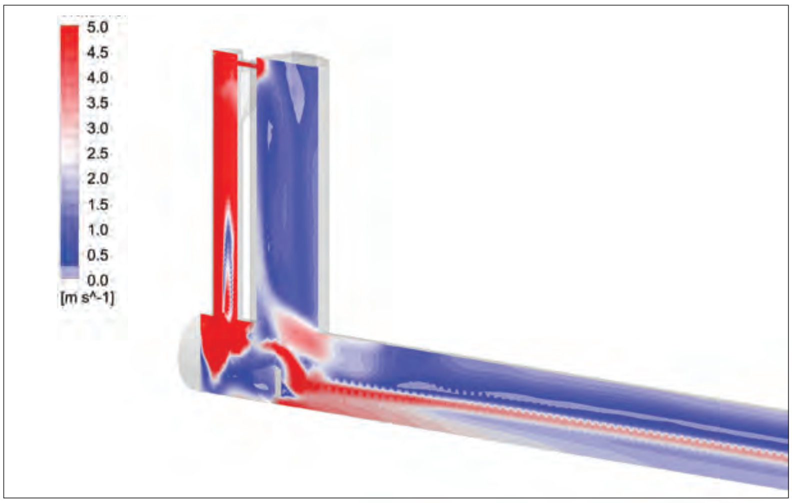
Two different solutions are necessary. At Inner Bair Island, Arup is using a vortex generator so that the waste water dissipates energy as it spins down the vortex drop tube, landing in a stilling pool at the bottom. At San Carlos, there were two pipes entering at different levels, so a vortex generator would not have worked, says Wilkie.

"At San Carlos, we are using a stepped cascade which is a shaft with a series of shelves so that the water never drops more than five or six feet," says Wilkie. "That gives us flexibility to accommodate different invert levels."

Designing the structures 'in the round' with constructor and operator has been an "iterative process" says Wilkie. "It's not just the best hydraulic system that we need. We are looking at how it will work with the ventilation system, how we can make the best use of temporary excavations for the permanent works, is it safe to build, can it be safely inspected?"

The shafts have also been challenging from a construction planning perspective. All three shafts – the launch shaft and those at Inner Bair Island and San Carlos – are subject to restrictions due to their proximity to San Carlos Airport. That means that

Work has started on site with Malcolm Drilling constructing the TBM launch shaft.



Where flow joins the new tunnel at Bair Island, designer Arup is using a vortex tube and stilling pool to dissipate the energy of the incoming wastewater.

Barnard-Bessac has had to work with both the airport and the Federal Aviation Administration (FAA) to determine what height they can raise construction equipment to. At the launch shaft, the limit is 65 feet above ground level (AGL)(20m), at San Carlos it is 21 feet AGL (6.4m) and at the Inner Bair Island shaft, the limit is 53 feet AGL (16.2m).

"It does limit your options and drives up your price a lot of the time," says Strid. "You have to choose a methodology that can operate at those heights." So, for instance, for the construction of the 84 ft (26m) deep slurry walls at the launch shaft that is currently underway, Malcolm must install the rebar cage in three sections, joining each bar to the next one with a coupler. The launch shaft must be ready to receive the TBM by September this year, with the machine due to arrive on site from Germany in July. Meanwhile Shea-Parsons, which won the contract for the headworks at the treatment plant, has started construction of the 65-foot (20m) deep receiving shaft – which will function as a surge and flow splitter shaft in the permanent condition.

Barnard-Bessac and Shea-Parsons are currently agreeing the details of the breakthrough panel in the shaft, for when the TBM is due to hole through in March 2021. "That is another benefit of progressive design build," comments Jaeger. "Both teams have to be in the same meetings discussing interface points, air flow and dynamics, helping to make sure that the system is operating the way the client expects it to operate." So for instance, a collective decision was taken to carry out all odour control at the headworks facility.

The progressive design-build approach also meant that the EPB machine, which has a lead time of 11 months, could be procured from Herrenknecht before the Stage 2 contract was signed. SVCW also authorised the early purchase of a $3.5million specialist crane for the launch site, which is being built especially for the project.

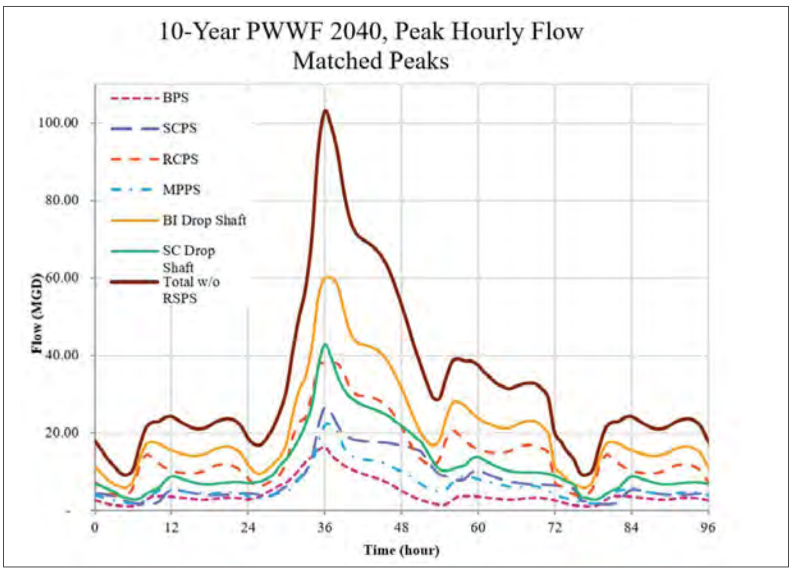
Verdict so far

Progressive design-build does require all those round the table to think and behave differently. Herrera flags up the need to train both operational staff and board members in the approach so that they understand the process and are committed to it. "We held weekly meetings for over six months to describe the process that we were embarking on so that our staff's understanding and expectations were crystal clear," she says.

Jaeger, who has been working at the Silicon Valley facility since 2013, says that the progressive design-build approach has allowed SVCW's staff to be included in the decision making. "Their ideas might not always have been taken on board, but at least they can see why the decisions have been taken. They all bought into the client's success factors, which were built into the RFP and helped guide our decision-making."

Speaking from a contractor's perspective, Catalano singles out the collective creation of the GBR as a particularly good outcome. However, he believes that the whole process could be pushed further to involve greater risk sharing between the parties, in order to deliver even better value. "The collaboration between the two sides during stage one was interesting. Maybe we could have gone a little further, but as this is a new concept, maybe it takes a little more time for everyone to get used to it."

For Herrera, the experience so far has been positive. "I think a fallacy of design-build is that it is suited for simple projects; I've learned that the exact opposite is true and that the more complex the project it, the more you want experts around the table (particularly builders) solving the complex problems."



The new pipeline and connecting structures must cope with a huge variation in flow rates.