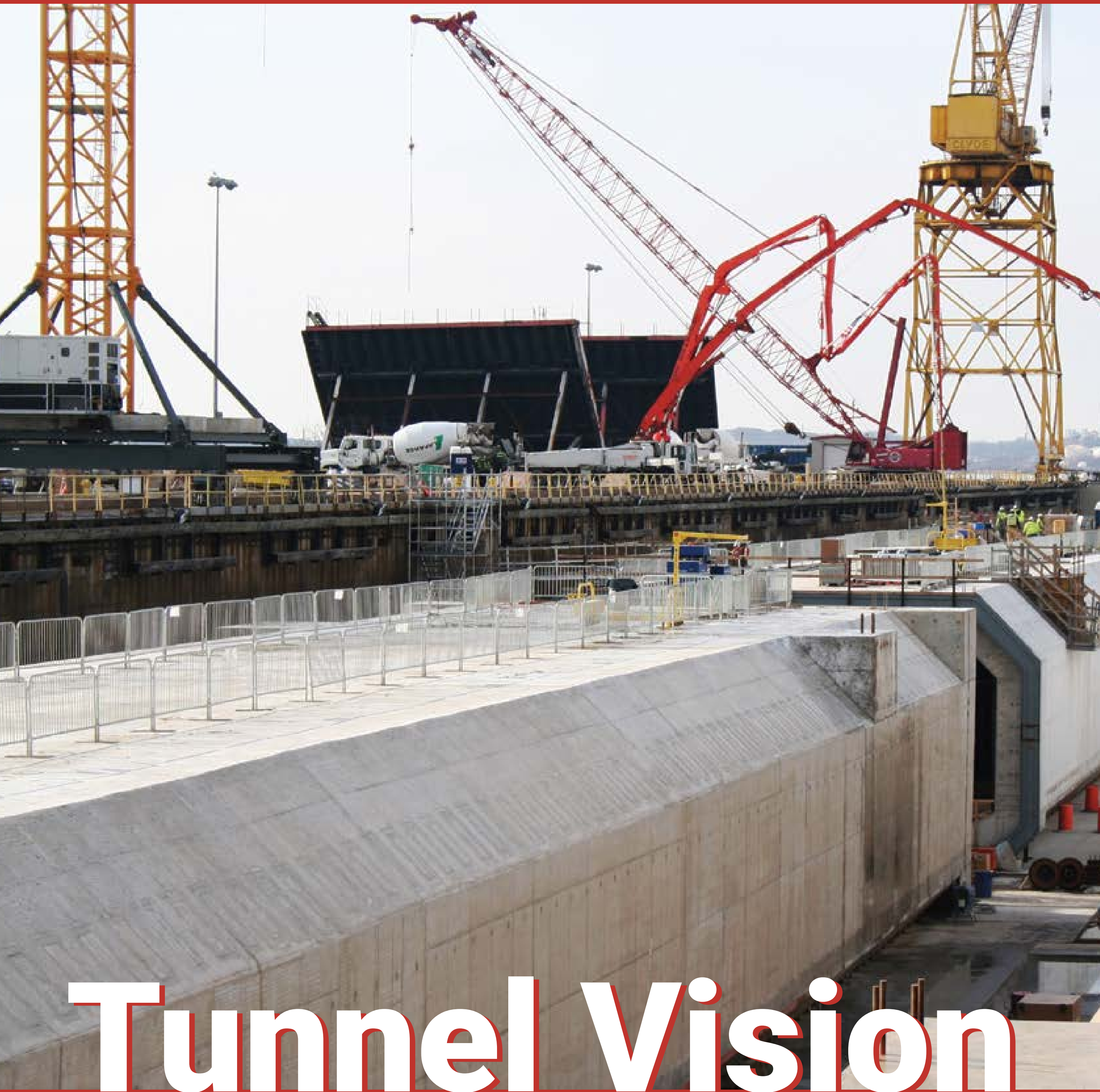

Tunnel Vision

A massive underground tunnel project in Virginia is made possible thanks to cost-effective precast concrete.

By Shari Held

Workers pour concrete for one of the tunnel's 11 massive precast segments.

Virginia's $2.1 billion Elizabeth River Tunnels Project, connecting Norfolk and Portsmouth, is one of the largest infrastructure projects currently underway in the U.S. The cornerstone and most challenging piece of the multi-faceted project is the new, two-lane Midtown Tunnel, built entirely of precast concrete.

It's only the second immersed tunnel in the U.S. to be built from precast rather than traditional steel-shell construction. While the project's precursor – the Fort Point Channel Tunnel in Boston – is impressive, it isn't quite as deep or complex as the Midtown Tunnel. When Midtown is completed late next year, it will reach a depth of 95 feet and carry more than 1 million vehicles per month.

Although steel-shell tunnels are still a popular choice for these projects, precast is the wave of the future.

"In Europe, precast is the method of choice now, and we expect this trend to continue in the U.S.," said Wade Watson, SKW Constructors project director. "In our case, with the price of steel these days and the concrete technology we now have, concrete was a better and more cost-effective solution."

Two important factors contributed to the decision to use precast concrete: access to an old graving dock at Sparrow's Point, Md., where the precast segments could be fabricated, and a shipping channel deep enough to float the immense concrete segments without venturing into the ocean.

The Virginia Department of Transportation and Elizabeth River Crossings OpCO, LLC hired SKW Constructors, a joint venture of construction companies Skanska, Kiewit and Weeks Marine to handle the $1.5 billion design-build portion of the project.

"We had tunnel-building background knowledge on the immersed steel-shell method, and there are some similarities, such as preparing the river bottom to accept the tunnel, that we were well-versed in," Watson said. "But we spent a lot of time going around the world, looking at other concrete tunnels and the issues they had, and we used that to our advantage on this project."

PREPARATION, PREPARATION, PREPARATION

Preparation, flexibility, and trial and error were essential. This is especially true for a project with so many constraints and unusual requirements, including a

120-year service life, confined egress corridor for fire control and evacuation, and jet fan ventilation.

Developing a concrete mix that could meet all of the requirements was the first challenge. The concrete had to have a service life of 120 years in an extremely corrosive environment without using corrosion inhibitors. In addition, it had to reach 6,000 psi at 28 days. It also needed to be extremely durable, yet flowable enough to accommodate double and triple mats of No. 11 black rebar.

Each of the 11 segments used to create the two tunnel elements is 350 feet long, 54 feet wide and 29 feet tall, weighing 16,000 tons a piece. Keeping the weight within tight tolerances was critical since the segments needed to float downriver. Another challenge was the sheer size of the segments and the fact that no two segments are the same.

"When you put all those parameters in one bag, it's difficult to find a solution," Watson said.

But they did. June 2013 to April 2014 was dedicated to engineering studies and development, batching and sample testing. The result was a unique, low water-cement ratio self-consolidating concrete mix that often reached nearly 10,000 psi at 28 days.

"We did over 120 mix designs to come up with the one we finally used," said Daniel Francis, SKW project engineer and construction manager.

SKW also created mini mock-ups to prove their methods and improve their techniques before creating a full-scale mock-up measuring 50 feet wide, 70 feet long and 30 feet tall, another project requirement.

"It was quite an investment, but having it on site proved to be very useful in the long run because we could use it for testing," Francis said.

A TRICKY PROCESS

The low-water mix didn't transport well. As a result, the concrete had to be batched, mixed and poured at the graving dock and then immediately placed into the formwork. SKW hired Lafarge North America's Sparrows Point location to set up two plants – one as a back-up – at the graving dock.

"The mix was extremely difficult to make and keep consistent," said Kirk Deadrick, Lafarge project manager for the batch plants. "Because of its challenging composition, we tested every load of concrete. Our quality assurance and quality control process played a critical role in the project, since any mix mistakes would be very time-consuming and costly to replace."

Lafarge made up to four pours per week. The bottom section of the tunnel segment was poured first. Then, formwork travelers were placed inside the tunnel to create the void where the traffic and utilities would run.

It took seven days to cure each segment. Controlling the differential thermal movement of a 350-foot segment was another major challenge. To address cracking concerns, the difference in the temperature could not exceed 35 F, and similar temperatures needed to be ensured throughout the entire placement process. SKW overcame this challenge with a complex thermal and cooling plan that involved cooling pipes, heating

Tugboats helped pull each precast segment downriver to its final destination.

pipes, blankets and liquid nitrogen.

"Because these elements were 350 feet long, it was a much bigger deal to control as we built each segment of the elements," Francis said. "The size and scope of what we were asking these precast elements to do was unheard of."

THE BIG FLOAT-OUT

To prepare the underwater site, SKW dredged a 60-foot-wide trench for the tunnel, excavating approximately 1.2 million cubic yards, or 85,000 filled dump trucks, of sediment. They then laid 40,000 tons of aggregate and sand approximately 2 feet thick and used a screed barge to grade it within a 1-inch tolerance.

To accomplish this feat, a split-hole arrangement was employed to control the vertical movement of the barge. This ensured the 60-foot blade below the water would always be positioned directly beneath the above-water carriage whenever the carriage was moved, allowing workers to achieve the tight tolerance.

To help the segments float, temporary bulkheads were installed at each end. Every segment was also designed with a ballast water exchange system consisting of 12 water tanks to control flotation and immersion.

The float-out of the six segments that compose the first tunnel element took place in summer 2014. The remaining five segments floated out this spring. Each of the segments needed to remain 2 1/2 feet above the water line while a tugboat pulled them down the Chesapeake Bay and Elizabeth River.

"If they sat any further down in the water we wouldn't be able to tow them," Watson said. "They'd just do a nosedive when pulled by the tugs."

It took 3 to 4 days, depending on the tides, for a segment to reach its destination. Placement began on the Portsmouth side of the river, adjacent to the existing Midtown Tunnel.

PERFECT POSITIONING

Plenty of ingenuity went into the precise placement of each segment. GPS technology was used to control horizontal and vertical placement. Once a floating segment was positioned close to its immersion site, 3 million pounds of concrete ballast was added to the bottom of the tunnel to help form the curvature for the road and add weight.

After this process was complete, the segment was placed onto a pipe-laying barge and hooked to the vessel's massive hoists. The water tanks were then filled so the segment could be lowered to the bottom. A total of 4 million gallons of river water was used to submerge the segments. Once a segment was within 3 feet of its resting place, hydraulic cylinders took over the positioning. The process of placing one segment took 12 hours.

A series of three seals – a Gina seal, an Omega seal and concrete encasement – help ensure the integrity of the tunnel. The first seal, a Gina rubber gasket at the inborn end, was compressed against a steel plate on the outboard end of the connecting segment, creating a watertight seal. One unique aspect of the plate is that it was designed to be cast into the tunnel. To ensure a tight fit between the two segments, the ends of both were laser scanned. The two scans were then brought together in virtual reality.

"Daniel and his staff figured out how to judge the thermal cycle to actually cast them in the segment and meet the tolerance without welding in a secondary device," Watson said. "That was pretty amazing."

LOOKING AHEAD

The new Midtown Tunnel is expected to open in December 2016, five years from the time SKW was awarded the project. Thanks to extensive planning, the few bumps in the road were systematically and successfully overcome.

"I think one of the secrets of our success has been our great team of people," Watson said.

Now that the project's nearing completion, the SKW team is eager to use their newfound expertise to tackle another precast tunnel project. That goes for Lafarge, too.

"SKW was a good partner to have on such a tough project," Deadrick said. "Their on-site leadership was strong, their focus on safety was similar to ours and they knew what it took to build this complex project." **PS**

Shari Held is an Indianapolis, Indiana-based freelance writer who has covered the construction industry for more than 10 years.