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ON THE COVER:

Size Matters: Coastal Precast Systems of Chesapeake, Va., manufactured 59 precast, prestressed column caps weighing 300 tons each for the New NY Bridge project. Learn more about how these pieces and other precast concrete components will contribute to the bridge's projected 100-year service life on page 18.

Photo courtesy of Coastal Precast Systems.

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Photo courtesy of New York State Thruway Authority



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A large concrete bridge structure with multiple levels, supported by pillars, under a blue sky with clouds. The bridge is made of precast concrete blocks, showing a modular construction style. The sky is bright blue with some white clouds. The bridge has a wide, flat top surface and a series of vertical supports underneath.

Powered by the use of precast concrete products, accelerated bridge construction is transforming the way engineers approach bridge design.

By Eric Carleton, P.E.,
and Mason Nichols



Photo courtesy of Michigan Department of Transportation



Photo courtesy of Michigan Department of Transportation

A worker inspects bridge components for an accelerated bridge construction project in Michigan.

You may recall the small, stackable alphabet building blocks you played with as a kid when you were learning your ABCs. But ask an engineer or road builder about ABCs today and he or she will tell you the letters refer to accelerated bridge construction.

The Federal Highway Administration defines ABC as “bridge construction that uses innovative planning, design, materials, and construction methods in a safe and cost-effective manner to reduce the on-site construction time that occurs when building new bridges or replacing and rehabilitating existing bridges.”¹ As Tom Macioce, chief bridge engineer for the Pennsylvania Department of Transportation explained, ABC is all about speed.

“Accelerated bridge construction minimizes the amount of time we are impacting the traveling public,” he said. “It’s important to the public that we get in and get out as quickly as possible.”

As with any construction project, the materials chosen for the work help dictate the outcome. The only building material that can consistently and efficiently meet the FHWA’s ultimate goal of reduced on-site construction time is precast concrete. Engineers have recognized that many of the same benefits precast concrete

brings to the building industry, including increased quality control and service life, are crucial to ensuring the long-term success of ABC projects.

“We feel like if you’re casting a component and building it in a controlled environment, that component may very well have more durability to it,” said Dave Juntunen, bridge development engineer for the Michigan Department of Transportation.

Corey Rogers, engineer of bridge field services for MDOT, agreed, adding that precast provides additional advantages over other materials. “With a precast operation, your connections are usually a high-strength grout that gains strength really quickly so you can move on to your next stage within a matter of 12 hours or a day,” he said. “So time savings is a big thing, because you don’t have the cure times associated with cast-in-place concrete.”

EVOLUTION

Precast beam sections have been used successfully in bridge construction for a half century. But the effort to fully employ precast concrete components throughout the bridge structure



Photo courtesy of Michigan Department of Transportation

Using a slide-in technique, crews replaced a Michigan bridge in just four days.

began taking shape more recently through FHWA's "Highways for LIFE" program. This program, combined with the 2009 state-based "Every Day Counts" initiative, provided the perfect catalyst. Still, expanding the use of precast beyond beams to other critical bridge elements required additional research and full-scale demonstrations to overcome concerns and biases in the design and construction communities.

In 2007, the FHWA addressed these questions in a report entitled "Innovative Bridge Designs for Rapid Renewal: ABC Toolkit." The report was published in 2013, with supplementing information added in 2014. Selected concerns include:

- Higher initial costs.
- Lack of access for equipment or the need for large staging areas unavailable in urban locations. The use of smaller elements for superstructure and substructure that can be assembled on-site could overcome access issues.
- Lack of ABC standards that can be adopted regionally by states and prefabricators.

In 2015, many if not all of these questions have been answered, resulting in increased ABC installations across the U.S. Finn Hubbard, senior vice president for engineering firm Fish & Associates, presented on the "ABC Toolkit" initiative at the

Transportation Research Board's 94th Annual Meeting earlier this year. During his presentation, Hubbard indicated that eight ABC projects throughout the country have resulted from the initiative, including work in Arizona, California, Kentucky, Maine, Missouri, Rhode Island, Wisconsin and Michigan. Four peer-to-peer exchanges are scheduled later this year to disseminate successful ideas and lessons learned from each project.

States which have implemented ABC programs have benefitted considerably from sharing ideas, information and guide specifications with other DOTs. According to Juntunen, the ability for engineers to network has also resulted in significant strides in ABC techniques.

"I really applaud the FHWA and their 'Every Day Counts' effort, making it possible for us to go to workshops and get peer reviews with other states," he said. "It would be foolish for 50 states to be inventing these details, so we're learning from each other all of the time."

One venue for sharing ideas and cutting-edge techniques that has generated success is the National Accelerated Bridge Construction Conference. This year, the annual event will be held December 7-8 in Miami, Fla. For more information on the conference, visit 2015abc.fiu.edu.



Photo courtesy of Johnson, Mirmiran & Thompson, Inc.

Outside of Pittsburgh, Pa., the new State Road 288 bridge was built entirely of precast concrete substructure elements.

AWARD-WINNING ABC PROJECT IN PENNSYLVANIA

Widespread collaboration among U.S. DOTs has resulted in highly successful bridge replacement projects across the country. For Pennsylvania, the use of precast and ABC techniques is critical, as the state currently contains the highest number of structurally deficient bridges in the U.S.

Outside of Pittsburgh, one such bridge carried traffic from State Road 288 in Lawrence County over Wampum Run, and was an important artery for local residents and the trucking industry. Shutting the bridge down meant creating a 22-mile detour that would significantly impact the nearly 5,000 drivers that traversed it every day.

To minimize traffic disruption, the bridge was targeted for ABC replacement. According to Macioce, the 78-foot-long replacement bridge took only seven days to install, and was built entirely of precast concrete substructure elements. Precast products used in the new bridge included pile caps, wingwalls, cheekwalls,

backwalls and approach slabs. The bridge deck also consisted of modular precast units, which were connected together using ultra high performance concrete.

The SR 288 bridge was recognized last year at the National Accelerated Bridge Construction Conference in Miami, Fla. It received top honors in the precast bridge elements and systems category for its extensive use of precast and expedited project timeline. Thanks to the success of the project, precast will continue to play an important role for the more than 500 bridges that will be replaced in Pennsylvania using ABC techniques over the next 3 1/2 years.

FROM FOUR MONTHS TO FOUR DAYS

Like in Pennsylvania, ABC techniques have played a vital role in bridge construction and rehabilitation projects throughout Michigan. For one particularly busy interchange, construction crews used a special slide-in method to reduce overall construction time from more than four months to only four days.



Photo courtesy of Johnson, Mirmiran & Thompson, Inc.

The completed bridge was honored in 2014 at the National Accelerated Bridge Construction Conference in Miami, Fla.

In this approach, the new superstructure is assembled on temporary foundations next to the existing bridge. Once the new bridge is completed, high-powered jacks are used to help move it into place. This process was used at the Interstate 96 and Michigan State Road 50 interchange near Grand Rapids. According to Roger Safford, region engineer for MDOT, the interchange's location meant reducing closure time was a top priority.

"The largest carpool lot in the state is located in the shadow of this interchange," Safford said. "I can't emphasize enough the impact of [ABC] technology on this location."

For this project – only the third of its type ever completed in the state – engineers specified precast concrete box beams and MSE wall panels. The 4.5-million-pound bridge took between 6 and 7 hours to slide from the temporary substructure onto the permanent substructure. The success of the project and other ABC endeavors in the state has resulted in a new perspective on bridge work for MDOT engineers.

"We currently evaluate every bridge project now for ABC, and it's not a question of, 'Let's justify this as ABC,'" Rogers said. "We have to justify [a project] for not being ABC."

EASY AS...

While advancements in techniques and increased adoption of precast concrete products has helped improve ABC, more remains to be done to further enhance the process. Researchers at U.S. universities and engineers across the country continue to seek improvements in design, standards and construction methods. But no matter what the future holds, durable, time-saving precast concrete products will continue to be an important part of the equation. Refining the techniques that make ABC successful are complex, but the choice to specify precast should be as easy as A-B-C. **PS**

Eric Carleton, P.E., is NPCA's vice president of technical services.

Mason Nichols is the managing editor of Precast Solutions magazine and is NPCA's external communication and marketing manager.

(Endnotes)


- ¹ Accelerated Bridge Construction: Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems (FHWA-HIF-12-013)

Going Strong

The Winter 2013 issue of Precast Solutions magazine covered MDOT's first-ever foray into ABC (precast.org/new-approaches) in 2008. Construction crews prepared the Parkview Avenue Bridge over U.S. 131 in Kalamazoo County for precast bridge elements and systems construction with the hopes of finishing the project in 12 weeks. Thanks to the use of a variety of precast elements, the project was completed on time and considered a success.

Several sensors were placed inside of the Parkview Avenue Bridge to monitor its performance. According to Bruce Campbell, senior project manager with Parsons, the bridge has lived up to expectations.

"We did a physical inspection of the bridge last summer, and the only issue we found is that one of the cast-in-place wingwalls had some cracking," he said. "All of the precast elements are performing very well."

A large, multi-colored brick wall made of precast concrete blocks. At the bottom right, a concrete drainage structure is visible, with water flowing through it. The sky is clear blue.

Flexing Precast's Muscles

Through the use of precast concrete, Macrete's innovative FlexiArch system produces bridges with an extended service life.

By Mark Crawford



Photo courtesy of Macrete



Photo courtesy of Macrete

FlexiArch units are shipped flat to a job site, then lifted and placed on precast footings.

When most Americans drive over a bridge, they aren't wondering if it is going to collapse. But if some travelers do, you can't blame them – about 11% of all U.S. highway bridges are structurally deficient and need to be replaced.

According to the American Society of Civil Engineers' 2013 "Report Card for America's Infrastructure," the average age of the nation's more than 600,000 bridges is 42 years. One in nine of these bridges is classified as structurally deficient. The Federal Highway Administration indicates that, in order to repair or replace all deficient bridges by 2028, the U.S. needs to invest \$20.5 billion annually in bridge construction, a 70% increase from current spending.

Steel reinforcement is a major reason bridges can deteriorate at such a young age. While using steel allows for faster installation of longer spans and slender beam bridges, it can rust and corrode, weakening the structure. Another option is masonry arch bridges, which are well known for their strength, durability, longevity and minimal maintenance. These factors, combined with their good looks, make them highly popular.

Thanks to a unique new system developed by Northern Ireland-based precast manufacturer Macrete, designers and engineers are turning to precast concrete instead to minimize costs and construction time while building bridges which will last several hundred years.

AN INNOVATIVE SOLUTION

The new arch bridge system was created by the School of Civil Engineering at Queen's University in Belfast, Ireland, in partnership with Macrete. Adrian Long, a civil engineering professor at Queen's University's Center for Built Environment Research, invented the system, which contains no steel reinforcement or mortar joints and is ideal for short-to-medium-span arch bridges. Called "FlexiArch," bridges built with the



Photo courtesy of Macrete

No reinforcing steel is required for FlexiArch bridges.

system require no centering and can be assembled in a day. These advantages make FlexiArch cost-competitive, especially when taking longer service life and reduced long-term maintenance into account.

HOW IT WORKS

FlexiArch bridges use the same basic construction principles as traditional stone masonry bridges. Because the main forces are compressive, no reinforcing steel is required. Voussoirs are manufactured using precast concrete for easy transport and rapid assembly, with angles calculated to produce the correct curvature of the arch when completed. They are then laid side by side and a layer of polymeric reinforcement is placed on top. Finally, a 1 1/2-inch layer of screed is overlain, assuring the voussoirs are interconnected.

FlexiArch units can be cast in convenient widths to suit design requirements, site restrictions and available lifting capacity. The units are transported to the project site flat, then lifted and placed on precast footings. When lifted at the designated anchor points, gravity forces the wedge-shaped gaps to close into the desired arched shape. All of the self-weight is then transferred from tension in the polymeric reinforcement to compression in the voussoirs, functioning the same way as a conventional masonry arch.

Each unit can be placed on site in as little as 10 to 15 minutes. "The degree of taper of the voussoirs controls the geometry of the arch," Long said. "Flatter arches require less taper and vice versa."

An integral part of the design is the polymeric reinforcement. The primary function of the reinforcement is to provide enough tensile strength for the FlexiArch units to be lifted safely from the flat casting bay to the flatbed truck, then from the truck into position on the precast sill beams at the bridge site.

"With safe working conditions being of primary importance,



Photo courtesy of Macrete

Construction crews installed 14 FlexiArch units to strengthen Tameside's aging Jubilee Bridge.

we accurately simulate the boundary conditions through carefully designed tests to ascertain the strength of the polymeric reinforcement," Long said. "Using these results and taking account of creep effects, an appropriate load factor can be applied to eliminate any risk of failure during lifting."

FUTURE PLANS

Only a few arch bridges have been constructed in Europe since the early 1900s thanks to the advent and popularity of reinforced concrete beam and slab systems. Since FlexiArch began business operations in 2007, more than 50 FlexiArch bridges have been constructed in the U.K. and Ireland. Span lengths range from 13 to 52 feet with plans for bridges as long as nearly 100 feet.

FlexiArch can also be used to strengthen existing bridges. For example, Tameside's 78-year-old Jubilee Bridge, which spans National Cycle Route 66 in Manchester, had been weakened by extensive reinforcement corrosion and spalling. The bridge could not be replaced because it was part of a key transportation corridor and would have disrupted services. Concrete was sprayed on the deck soffit in 1974, but was not expected to be a long-term solution.

In December 2012, the main contractor installed 15-foot-long FlexiArch units. The 24-foot span units were manufactured off site and shipped to the bridge location. A crane individually lifted the spans, which were placed on lightly greased, laterally extended sill beams along each abutment. They were then pushed horizontally in pairs beneath the bridge using two hydraulic jacks.

"When all 14 units had been located, spandrel walls were constructed and the gap between the FlexiArch unit and the original deck soffit was filled with foamed concrete," Long said. "The result was an aesthetically-pleasing bridge with a design life of 120 years."

The greatest initial challenge for Long was convincing precast



Photo courtesy of Macrete

The upgraded bridge boasts a new design life of 120 years.

manufacturers that FlexiArch was a viable bridge system. It was also difficult to get the first bridges built because clients and their consultants were reluctant to be the first to use the new concept. Discussions are in progress with companies in Australasia, Sweden and the U.S., and several U.S. precast companies are exploring sub-licensing agreements.

Lengths could be even longer for pedestrian bridges – the FlexiArch units could be transported in two lengths for interconnection prior to installation. The system could also be adapted for skew arch bridges over railway lines, where speed of construction is paramount.

"For angles of skew of around 30 degrees," Long said, "slightly modified voussoirs could be beneficially deployed. Also, using FlexiArch in conjunction with stress ribbon decks would result in very graceful pedestrian bridges over motorways."

After contractors, designers and clients have been involved in the installation of a FlexiArch bridge they become strong advocates of the system.

"When this experience is combined with competitive cost, aesthetics, sustainability and durability," he said, "the potential for widespread use in the construction industry is immense." **PS**

Mark Crawford is a Madison, Wis.-based freelance writer who specializes in science, technology and manufacturing.



Photo courtesy of Smith-Midland Corp.

An office building with precast concrete cladding at Fort Belvoir in Virginia was completed in 12 months and earned a LEED Gold certification.

Serving the Armed Forces

Precast concrete is often recruited by the U.S. military for projects that require a strong and adaptable building product.

By Kirk Stelsel

The U.S. military subjects recruits to a series of tests, such as obstacle courses and written exams, to determine their mental and physical strength from the moment they step onto base.

When it comes to military building materials – especially those protecting soldiers or equipment – strength is also a critical

element. The military has built highly-fortified structures with concrete for decades, from Cold War-era missile silos designed to withstand nuclear blasts¹ to the Pentagon. Precast concrete in particular is used by the military for everything from basic infrastructure to custom products.



Photo courtesy of Easi-Set Worldwide

Workers install an Easi-Set building manufactured by Leesburg Concrete at MacDill Air Force Base outside of Tampa, Fla.

Here's a look at a few ways the U.S. military has deployed precast concrete at bases around the country.

MODULAR SOLUTIONS

Military bases are self-sufficient communities with all the needs and more of civilian cities. Like cities, bases use prefabricated precast concrete buildings for common applications such as storage, electrical buildings, field stations and restrooms. Other uses, such as ammunition storage and training simulations, are unique. Easi-Set Worldwide, based in Midland, Va., licenses a family of precast building designs used on many bases.

"Government officials often turn to us for military projects due to the ease of purchasing pre-engineered, pre-designed, precast concrete buildings," said Jeremy Smith, building product manager with Easi-Set. "The design and construction process is simplified, allowing projects to go to bid more quickly. Delivery and installation typically happen in the same day."

In Florida, Leesburg Concrete Company has experienced a growing demand for its Easi-Set precast buildings at government facilities. The company recently supplied a storage building and restroom to MacDill Air Force Base outside of Tampa, Fla. For Fort Benning in Georgia, it supplied a precast building that houses electrical equipment.

Modular construction saves time on site, but is also adaptable. Leesburg Concrete custom manufactured a storage building for MacDill Air Force Base which was strategically placed under the overhead beams of an inspection facility. The buildings supplied by



Photo courtesy of Superior Concrete Products

Superior Concrete's ballistics membrane can be added to any of its existing wall panel products.

Leesburg Concrete meet the strict requirements for secure military buildings.

IMPACT RESISTANCE

In 2011, a standard, 3-inch-thick Easi-Set building panel passed a Level 5 UL 752 ballistics test. During the test, a 150-grain, 7.62 NATO round was fired from 15 feet away at 12-inch-by-12-inch test samples in varying conditions.

Superior Concrete Products, based in Euless, Texas, unveiled its new Superior Ballistics wall product that has undergone separate, similar testing. The company initially developed the new product line as a response to an increasing number of utility jobs requiring a ballistics rating.

Superior includes a membrane in its traditional casting process to significantly strengthen the panels. It can be added to any of its current wall panel products, which the company designs to mimic materials such as brick, stone and wood. In addition to the finishes, the company uses integral color to match any color the customer



Photo Courtesy of U.S. Strategic Command

The new USSTRATCOM headquarters in Omaha, Neb., will be clad in blast-resistant precast concrete panels.

requests. Unlike the materials the walls mimic, Superior's precast wall systems install faster, have a much longer service life and lower maintenance costs.

"It's a decorative precast concrete fencing that we believe meets a different approach," said Mike Taylor, vice president of finance and administration for Superior Concrete Products. "It's friendly to the neighborhood and it's visually pleasing. It's a precise, high-quality product and everything is tested in our lab according to NPCA Certification standards."

Although the company is just beginning to bid jobs with the product, it has worked with the military in the past and anticipates future military business.

"I ran into an officer at World of Concrete and he was very interested in our products," Taylor said. "He saw our product and he complimented it. We have their needs in mind when it comes to being professional and providing high-quality products and helping secure our nation."

WALL-TO-WALL SECURITY

Strength is also a major requirement for new construction on bases. On a 4-story building at Fort Belvoir in Virginia, the Army Corp of Engineers and the project architects achieved a number of goals using brick-finish Easi-Set Slenderwall panels from Smith-Midland Corp. in Midland, Va. Completed in just 12 months, it earned a LEED Gold certification and matches the look of other buildings on base while meeting anti-terrorism guidelines.

"The selected wall system already had approvals for meeting the strict anti-terrorism criteria for security and blast resistance," said Matthew Smith, vice president of sales and marketing for Smith-Midland. "Yet it is a lightweight method of only about 30 pounds per square foot, mounted outboard of the floor slab."

More than 1,000 miles to the west, the U.S. Strategic Command is currently constructing a \$1.2 billion facility at Offutt Air Force Base in Omaha, Neb., with precast concrete wall panels.

USSTRATCOM is responsible for detecting, deterring and preventing strategic attacks against the U.S. and its allies. The Command is vital to U.S. security and also serves as backup to both the Pentagon and U.S. Northern Command.

"Including components, the Command employs more than 4,100 people, representing all four military services, and Department of Defense civilians and contractors, who oversee the Command's global operations – 24 hours a day, 7 days a week," said Lt. Col. Martin O'Donnell, USSTRATCOM public affairs current operations chief.

The Command constructed its current facility nearly 60 years ago. As O'Donnell stated, it was "built to support typewriters and grease boards." Planning and design of the new facility was a multi-year process and construction is underway. Reliability and security are paramount, particularly with the Command's role as backup to other top military installations.

The new facility will include 84,311 square feet of precast including columns and blast-resistant façade panels with brick and acid-etched finishes. In addition to securing the building, the precast provided the U.S. Army Corps of Engineers with other benefits.

"At USSTRATCOM, the biggest benefit of using precast concrete members is that they are manufactured under strict quality control processes," said Richard Taylor, assistant chief, Engineering Division, Omaha District, U.S. Army Corps of Engineers. "This ensures that the products are consistent in appearance from member to member. Fabrication off site also eases congestion at the job site and allows for on-time delivery and erection."

THE PERFECT PARTNERSHIP

The list of precast concrete products used on military bases is long. Cape Fear Precast in Jacksonville, N.C., supplies five bases in the area. Products have included sewer and water infrastructure, custom vaults to store firefighting foam and firing range products.



Photo courtesy of Western Precast Concrete

Precast concrete barriers manufactured by Western Precast Concrete in El Paso, Texas, were used during military training at Fort Bliss.

Western Precast Concrete in El Paso, Texas, has a long-term relationship with Fort Bliss, a local U.S. military post. One of the largest projects was an order for nearly 300 units of precast concrete military barrier used for a training facility. The barrier helped simulate conditions a soldier might encounter while deployed to a combat zone.

"In addition to a limited level of blast protection around the perimeter, the barrier was also staged as a component of force protection infrastructure known as an entry control point system," said Richard Alvarado, general manager and quality control director for Western Precast and a veteran of the Iraq War. "The training provided by this installation is invaluable. It can prepare troops for scenarios that include security clearance and protocol response to attacks such as vehicle improvised explosive devices."

And Smith-Midland is no stranger to training products either. It manufactured roof slabs, walls and prefabricated buildings to help the Marines construct a mock Afghan village inside a warehouse. The color and finish on the product mimics adobe mud huts to help make the simulation as realistic as possible.

MISSION ACCOMPLISHED

Whether it's troop training, security or infrastructure, the U.S. military has put precast concrete products to the test at installations across the country. From a hurricane-resistant U.S. Coast Guard hangar in the Bahamas (precast.org/hangar) to an all-precast administrative building in Texas (precast.org/built-army), examples are everywhere. As evidenced by continued use, precast has lived up to the high expectations. **PS**

Kirk Stelsel is NPCA's director of communication and marketing.

(Endnotes)

¹ http://www.strategic-air-command.com/missiles/Titan/Titan_II_missile_complex.htm

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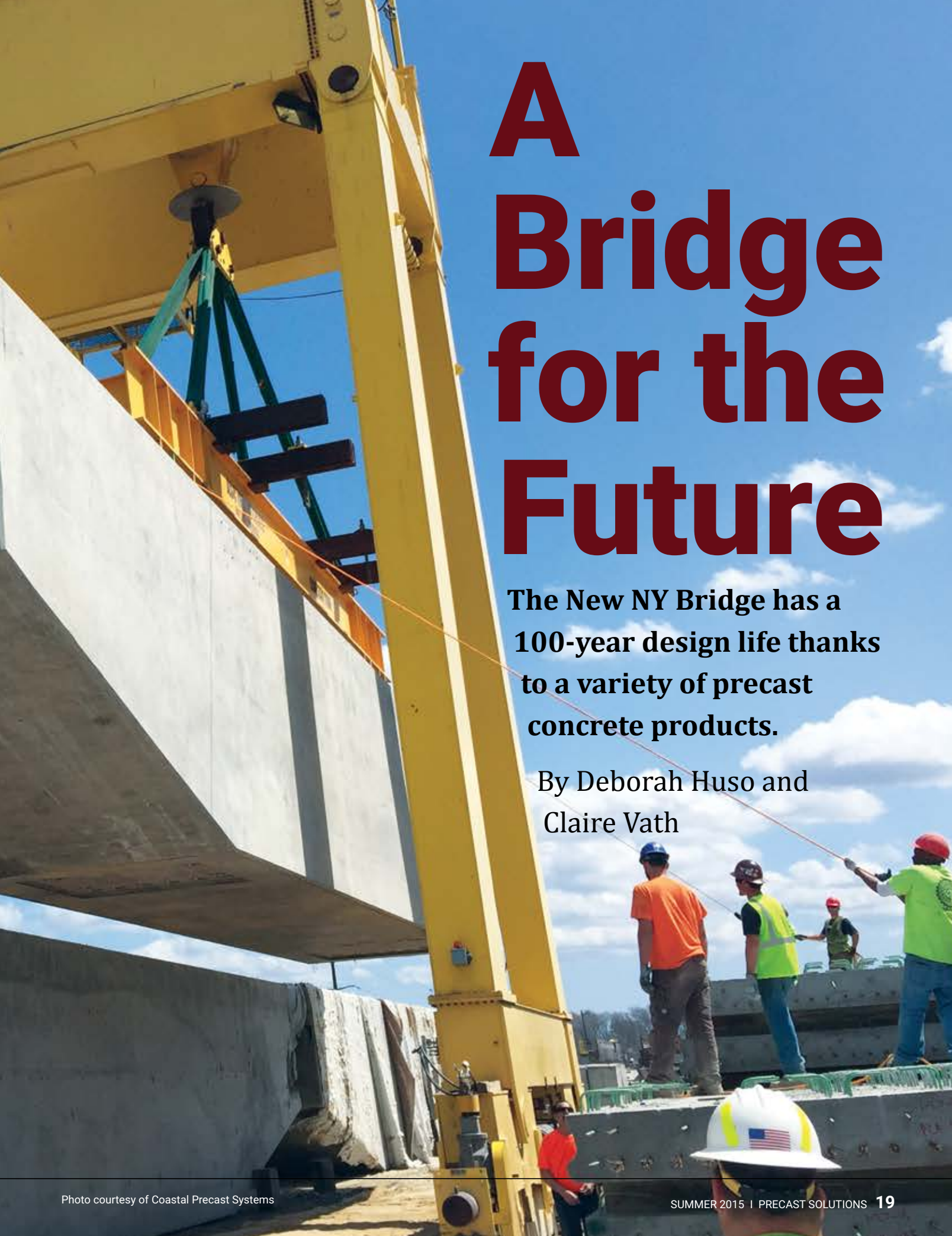
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A Bridge for the Future

The New NY Bridge has a 100-year design life thanks to a variety of precast concrete products.

**By Deborah Huso and
Claire Vath**



Photo courtesy of New York State Thruway Authority



Photo courtesy of New York State Thruway Authority

Workers oversee installation of precast components on site at the \$3 billion New NY Bridge project.

Project: The New NY Bridge

Location: Lower Hudson Valley,
New York

Builder: Tappan Zee Constructors,
Tarrytown, N.Y.

Owners: New York State Thruway
Authority and the New York State
Department of Transportation

Precasters: Coastal Precast
Systems, Chesapeake, Va.;
Unistress Corp., Pittsfield,
Mass.; The Fort Miller Company,
Schuylerville, N.Y.; Bayshore
Concrete Products Corp., Cape
Charles, Va.



Photo courtesy of New York State Thruway Authority

An hour north of New York City, the Hudson River carves out a deep valley, winding through a landscape of towns and woods before narrowing into the Catskills. Spanning a 3-plus-mile stretch of the river above the city, the Tappan Zee Bridge's graceful S-shape helps connect key areas of the lower Hudson Valley. The bridge's west end begins in Rockland County's South Nyack community and meets Westchester County's Tarrytown on the eastern shore.

The bridge's poetic moniker can be broken down into two components. "Tappan" derives from the Tappan Native American tribe who settled the area. "Zee" is the Dutch word for sea. What's not so poetic, though, is the bridge's crumbling infrastructure, which bears the load of 138,000 commuter vehicles each day. In 2018, the New NY Bridge will officially replace the Tappan Zee, which opened in 1955.

When complete, the new 3.1-mile, double-span, cable-stayed bridge will feature eight lanes, four breakdown lanes, a bicycle and pedestrian path, state-of-the-art traffic monitoring systems and accommodations for future commuter rail transit. The \$3 billion bridge project is the largest in New York history, and the building team, Tappan Zee Constructors, promises a structure that will last for at least the next century with no major maintenance.

To achieve that long-lasting service life, engineers and builders

have figured substantial precast concrete components into key elements of the new bridge design. These elements will help bear the load requirements on the heavily traversed road deck panels and support the bridge's foundation.

BRIDGING A CENTURY

TZC, a consortium of construction, engineering and design firms, leads the bridge's construction in partnership with the New York State Thruway Authority and the New York State Department of Transportation. Following geotechnical and environmental investigation of the subsoil and bedrock to determine the ideal location for the bridge's pilings and an assessment of environmental impacts on marine life, construction officially began in August 2013.

Contractors sunk massive steel pilings into the lower Hudson River to form the bridge's foundation and load-bearing capacity. They then placed precast pile caps on top, unifying the supportive strength of the individual piles at the river's surface and creating a strong base. The bridge's main span pile caps, or footings, run longer than a football field in order to support its main towers. The approach spans – which carry traffic from land to the main span – feature 70 precast concrete pile caps.

The approach span pile caps are approximately tennis-court-



Photo courtesy of Coastal Precast Systems

Coastal Precast Systems manufactured 59 precast column caps for the bridge, each weighing 300 tons.

size concrete tubs. The bottoms of the tubs, manufactured off site by Bayshore Concrete Products Corp. of Cape Charles, Va., feature a series of holes slightly larger in diameter than the pilings. The holes match up to the piling pattern, and once delivered to the job site, barge-mounted cranes position each pile cap over the pilings. Workers carefully thread the holes onto the pilings as though fitting together a puzzle. The pile caps sit partially submerged 6-to-8 feet below the waterline.

Next, builders seal each pile cap with concrete around the holes and pump out any remaining water in the tub. Workers then lay a labyrinth of zinc-galvanized rebar throughout the tub. Zinc minimizes corrosion while the steel cage stands up to immense tension. Up to 750 cubic yards of standard concrete – poured from one of the project’s two on-site floating batch plants – fills the remaining tub space. The concrete strengthens the footing, allowing it to withstand incredible compression, transferring the loads from the bridge superstructure, columns and caps into the piles.

To stand up to marine conditions, the footings, which sit partially below water level, need to be surrounded by sheet pile.

Alternatively, “you can use precast concrete, which stands up to the conditions,” said Joe Rose, vice president of sales for Coastal Precast Systems of Chesapeake, Va. “Using precast concrete footings saves on time and construction costs.”

CPS manufactured the column caps that sit atop the columns of the bridge’s approach spans. The column cap, Rose explained, helps support the steel beams that create the superstructure.

Overall, CPS is manufacturing 59 column caps, which run on each side of the bridge. The massive precast, prestressed structures weigh approximately 300 tons each and measure either 83 or 92 feet in length, depending on whether the unit is for the eastbound or westbound structure. Each tub-shaped piece is 13 feet tall and 10 feet, 6 inches wide, with 10-inch walls and a 1-foot-thick floor.

Intermediate diaphragms – divided, chamber-like precast structures that strengthen the tub from collapse – make up the interior. “The diaphragms support the dead load of the wet concrete when the tubs are in final position,” Rose said.

Galvanized rebar and strand then snake through the infrastructure. A monolithic pour, consisting of 150 cubic yards of



Photo courtesy of Coastal Precast Systems

Each of the massive column caps measures nearly 100 feet long.

concrete, fills up to where the beam superstructure bearing seats will be cast, finishing the tub.

CPS also manufactures the bridge's seal slabs, precast sections that create a casting platform for the main span and support span towers. The 22 anchor seal slabs – made up of 11 pieces each – are 18 inches thick. The largest end sections measure 35 feet wide by 43 feet, 10 inches long, and weigh 145 tons. The tower seal slabs consist of 30 pieces of precast, with the longest running 38 feet by 29 feet and weighing 95 tons. Each slab is cast with a 7-foot-diameter opening to allow a 6-foot-diameter steel shaft to project through the seal slab floor.

CROSSING THE HUDSON

The bridge's driving surface is comprised of 5,960 precast panels on the approaches and 973 panels on the main span. TZC awarded Unistress Corp. of Pittsfield, Mass., a \$70 million contract to produce the approach's deck panels.

"[TZC] weighed several alternative design-build ideas, but when they looked at all alternatives, their engineers chose precast because of the critical construction time schedule, as well as

the need for a long-lasting, quality product," said Perri Petricca, president of Unistress.

Each precast panel runs 40 feet long and 12 feet wide. To construct the deck panels, galvanized reinforcing steel is pre-tied into cages. After the cages are placed into concrete forms, Unistress installs cast-iron scuppers, mechanical access boxes and isolation valves. Precast allows those extras to be added right into the concrete, eliminating the need for on-the-bridge installation.

Concrete then fills in the remainder of the panel. Steam curing accelerates the concrete curing process and improves panel durability. The process adds warm, moist air to the concrete, helping it reach an optimum temperature.

"Since precast is manufactured in a controlled casting environment, it's easier to control the mix, placement and curing," Petricca explained. "Any time you cure concrete in a moist environment, it adds strength and durability to the product. We also use a low water-cement ratio in combination with the steam curing to further create dense, highly durable concrete."

Panels undergo quality control to ensure full compliance with plans and specifications. Once panels leave the plant, they're



Photo courtesy of New York State Thruway Authority

Figure 1: Rendering of the completed New NY Bridge.

delivered to the job site, where a crane hoists them into place atop steel girders.

Because the panels are prefabricated, precast decking installation is much quicker than traditional cast-in-place and reduces workers' on-the-job hazards. "We are fabricating the panels concurrent with the construction of the piers and steel support beams, so once the steel is in place, the deck panels can be erected in a fraction of the time it would take to pour the deck in place ... and without potential adverse weather impacts," Petricca said.

Rose agreed with Petricca's assessment. "Precast eliminates the exposure to weather-related delays on the job site," he said. "Plus, the value is further enhanced because the plant-controlled casting provides a much higher quality of concrete."

REFLECTING ON THE BRIDGE OF TOMORROW

While precast concrete offers increased durability for both traffic and weather and saves time, helping keep the \$3 billion budget in check, a project of this caliber isn't always so straightforward.

"Handling the massive pieces of concrete is challenging," Rose said. "There's immense physical pressure when pouring these volumes of concrete. The intricacies of specifications and quality control measures are massive."

For Unistress' contribution, Petricca had to beef up staff to

handle the project's demand. "It's the largest project in Unistress history," he said. "We hired 138 new people and invested more than \$6 million to increase our production capacity."

The bridge, built to last 100 years without major maintenance, is something Petricca said owes to the use of precast. "Precast concrete offers stronger, more durable bridge elements over the lifetime of the bridge, with far fewer cracking and deterioration issues," he said. "The extensive use of precast concrete will certainly showcase its advantages in quality, durability, and installation, and should result in more projects designed with precast as the preferred solution."

The lower Hudson is a frenetic place these days. Workers, barges and cranes come and go. When complete, the New NY Bridge will be the world's widest and New York's priciest bridge project to date.

Final work wraps up in 2018, when the remnants of the old Tappan Zee Bridge will be completely dismantled. And, at least for the next century, the New NY Bridge will stand in its place – a testament to the durability of precast concrete and the innovation of the workers who came together to make it possible. **PS**

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Photo courtesy of Lisa Ricciotti

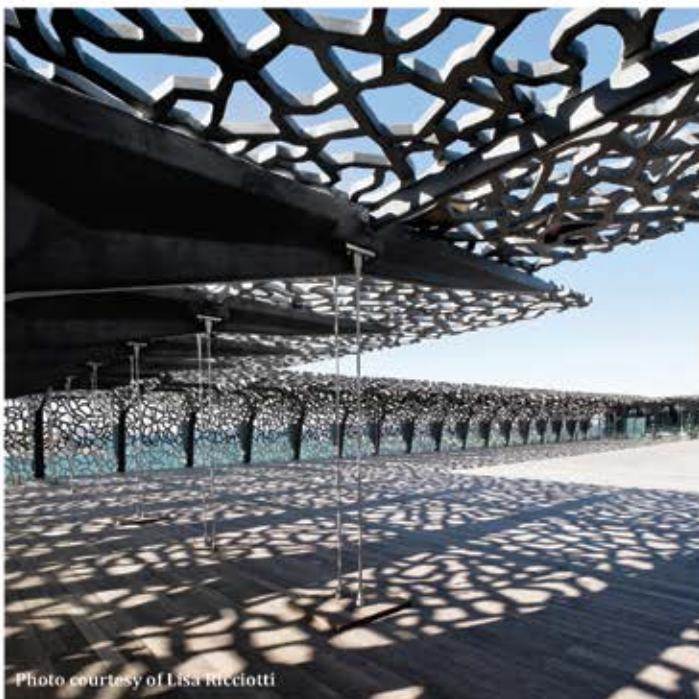


Photo courtesy of Lisa Ricciotti

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Staying Power

Nearly 1,000 large-scale precast concrete segments save construction time and ensure long-term reliability for the new St. Croix River Bridge.

By Kayla Hanson and Mason Nichols



Photo courtesy of Minnesota Department of Transportation

Each of the St. Croix River Bridge's 656 main span precast segments requires a single continuous pour of 90 cubic yards.

For thousands of years, bridges have been used to span obstacles and link people with places. Thanks to advancements in construction technology, modern bridges are as aesthetically pleasing as they are functional, evidenced by iconic structures across the world. Still, whether it's the Brooklyn Bridge in New York or the Great Belt Bridge in Denmark, all bridges are designed to create connections, bringing people together that would otherwise be separated by mountains, rivers or valleys.

Spanning the calm waters of the St. Croix River in Minnesota, the Stillwater Lift Bridge is no different. The bridge links Minnesota and Wisconsin and has enabled millions of travelers to navigate between the two states since its construction in 1931. But it provides only one lane in each direction, creating havoc for drivers of the 18,000 vehicles that traverse it each day. The Minnesota Department of Transportation partnered with Lunda/Ames JV to help reduce traffic congestion with the new St. Croix River Bridge. Anchored by the use of nearly 1,000 massive precast concrete segments, the bridge will provide a more efficient experience for all travelers when completed in fall 2016.

AN EXTRA DOSE OF PRECAST

Construction of the St. Croix River Bridge is part of a large-scale, \$600 million project that includes extensive roadway work

in Minnesota and Wisconsin, the creation of a trail system and conversion of the old Stillwater Lift Bridge to a pedestrian and bike path.

According to Michael Beer, project director with MnDOT, the new bridge will have two lanes in each direction to handle projected growth of up to 48,000 vehicles per day by 2036. Additionally, thanks to the use of the precast concrete segments, the bridge will boast a 100-year lifespan.

"One of the benefits of precasting is constructing the pieces in a more controlled environment," said Paul Kivisto, bridge construction engineer for MnDOT. "Using the precast concrete will help enable the bridge's extended lifespan and also enable us to put segments up at a faster rate than cast-in-place."

The bridge will be more than 5,000 feet in length when it is completed, making it one of the longest bridges in the state. Kivisto said it features an extradosed design, a style that limits tower heights and results in a smaller angle of inclination for the stay cables. The extradosed design will be the first for Minnesota and one of the first in the U.S.

RECIPE FOR SUCCESS

Each of the approach pieces for the St. Croix River Bridge is manufactured with a 0.32 water-cementitious materials ratio



Photo courtesy of Minnesota Department of Transportation

The bridge's approach segments await placement at the project's on-site casting yard.

using one of two mix designs – either 6,000 psi or 8,000 psi. Cementitious materials for both mixes consist of 70% Type I/II cement, 20% ground granulated blast furnace slag and 10% fly ash.

The main span segments, which are about twice the size of the approach pieces, are also produced using two mix designs – either 8,000 psi or 9,000 psi – both with a 0.30 w/cm ratio. The cementitious materials used in the 8,000-psi mix consist of 70% Type I/II cement and 30% fly ash. In the 9,000-psi mix, the cementitious materials are comprised of 65% Type I/II cement, 20% fly ash and 15% ground granulated blast furnace slag.

The mixes contain varying quantities of air-entraining admixtures and water reducers. Three types of reinforcing steel are also present in the bridge components: traditional reinforcing steel is used in the footings, epoxy-coated rebar is used in the above-ground components up to the top layer of the deck and the top surface of the deck uses stainless steel.

PUTTING IT ALL TOGETHER

Tackling a project of this magnitude comes with a number of challenges, ranging from casting techniques for manufacturing such large segments to the logistical issues associated with connecting them together. With dimensions measuring up to 18

feet high, 10 feet long and 48 feet wide, each of the 656 main span segments requires a single continuous pour of 90 cubic yards that can take up to 4 hours. Though casting the segments in place was possible, doing so would have significantly delayed the project timeline.

“The contractor had the ability to design cast-in-place on all of the bridge if they had wanted, but our plans were prepared with precast for a time component,” Kivisto said. “Precast has benefits – you can produce the segments while you’re constructing the substructures and then more quickly finish the superstructure during erection.”

Massive pieces such as these require significant care and attention not only in casting and curing, but also in transportation and placement. The smaller segments, which each consist of 45 cubic yards of concrete, are used in the bridge approach on land and manufactured at an on-site casting yard next to the construction site. The main span segments are produced 30 miles away from the construction site and travel by barge via the Mississippi and St. Croix Rivers to their final location.

“A single barge will be able to take 4 to 6 segments, but they’ll be shipping together with a couple of different barges,” Kivisto said. “So it could be 10 to 12 [segments] in a shipment.”

When the segments arrive on site, a crane positioned on the



Photo courtesy of Minnesota Department of Transportation

This summer, crews will place precast segments on three of the bridge's piers concurrently.

top deck of the bridge lifts them into position. Construction crews apply epoxy to the male face of one segment and the female face of the match-cast segment. After the epoxy is applied, the two shear key pieces are positioned together and post-tensioned.

BUZZ

Much like the match-cast precast segments, residents in both Minnesota and Wisconsin will benefit from the connection that will be made once the St. Croix River Bridge is completed in 2016. While much work remains, Beer said he believes both states will experience opportunities for growth made possible by the new structure.

"It's really exciting to see everything that's taken place and how quickly everything has gone up," Beer said. "There's a lot of interest and excitement about the project among the folks that live and work in the area."

Construction will intensify as the summer progresses, with crews placing precast segments on three of the bridge's piers at

the same time. The magnitude of the work should serve to further engage residents on both sides of the river.

"There will just be a buzz of activity going on out there for anyone that comes to look at the new bridge," Beer said. "It's nice to see that high level of excitement from not only the construction workers and owners' personnel, but the public as well." **PS**

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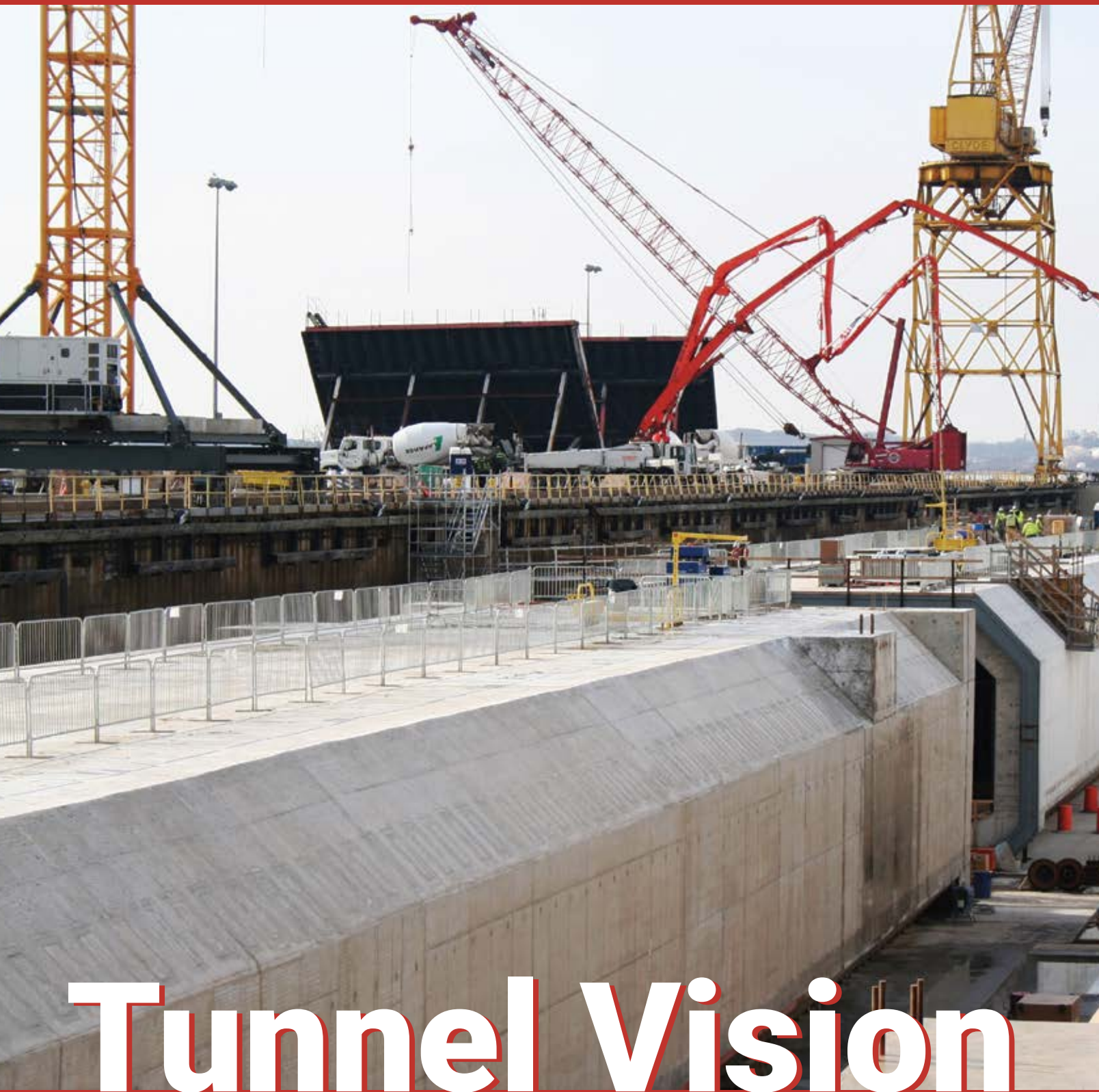


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Tunnel Vision

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

By Shari Held



Photo courtesy of SKW Constructors



Photo courtesy of SKW Constructors

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



Photo courtesy of SKW Constructors



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



Photo courtesy of SKW Constructors

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

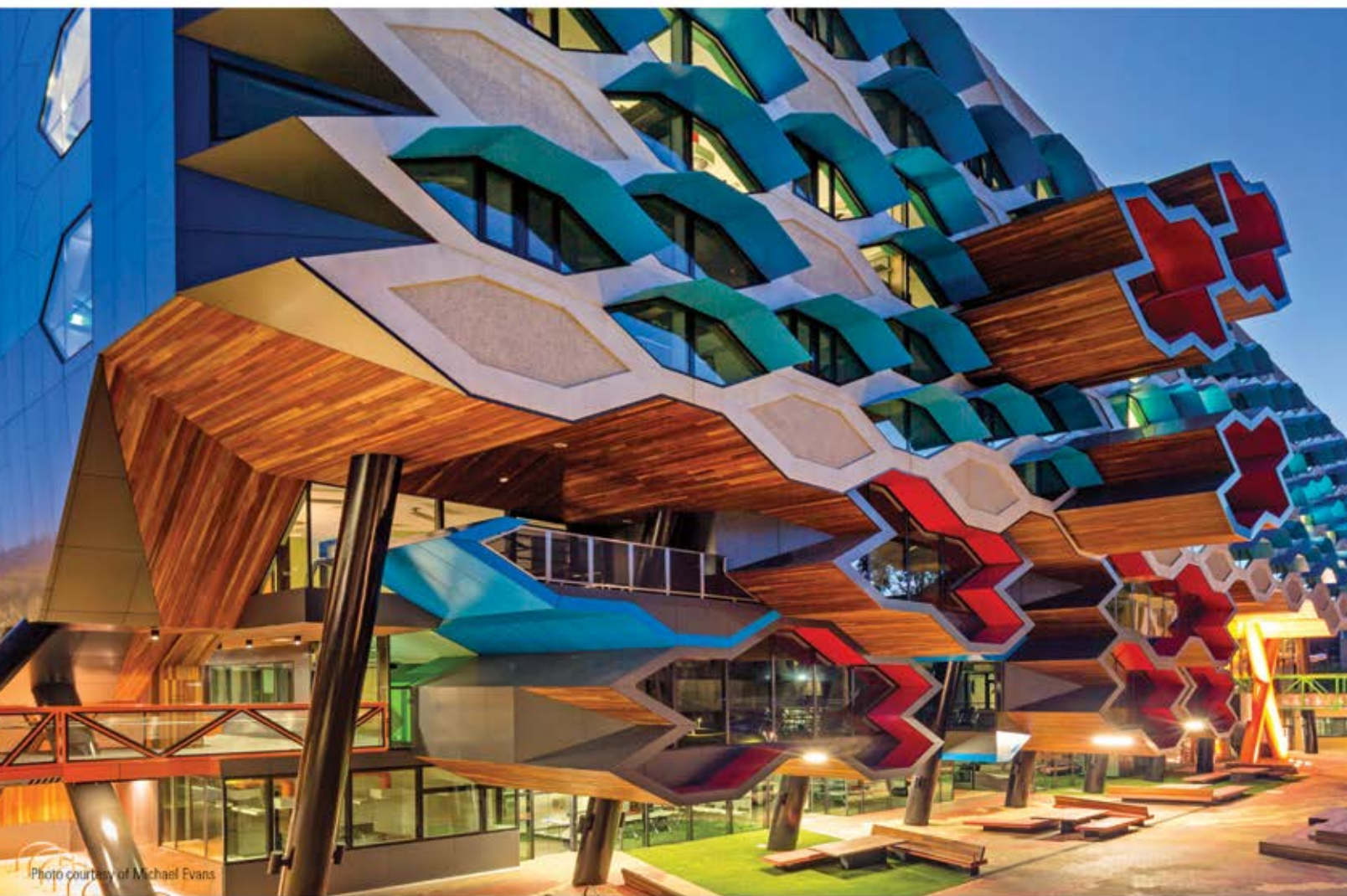
The new Midtown Tunnel is expected to open in December 2016, five years from the time SKW was awarded the project. Thanks to extensive planning, the few bumps in the road were systematically and successfully overcome.

"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.



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