Underwater Precast / Europe's Largest Infrastructure Project / Ultra High Performance Precast

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ON THE COVER:
Tunnel Vision: Eight tunnel-boring machines weighing 1,000 tons each helped place the 210,000 precast concrete segments required to build Europe's largest infrastructure project. Learn more about how London's Crossrail project is a game changer for the construction industry on page 16.

Photo courtesy of Crossrail Ltd.

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WHAT'S INSIDE

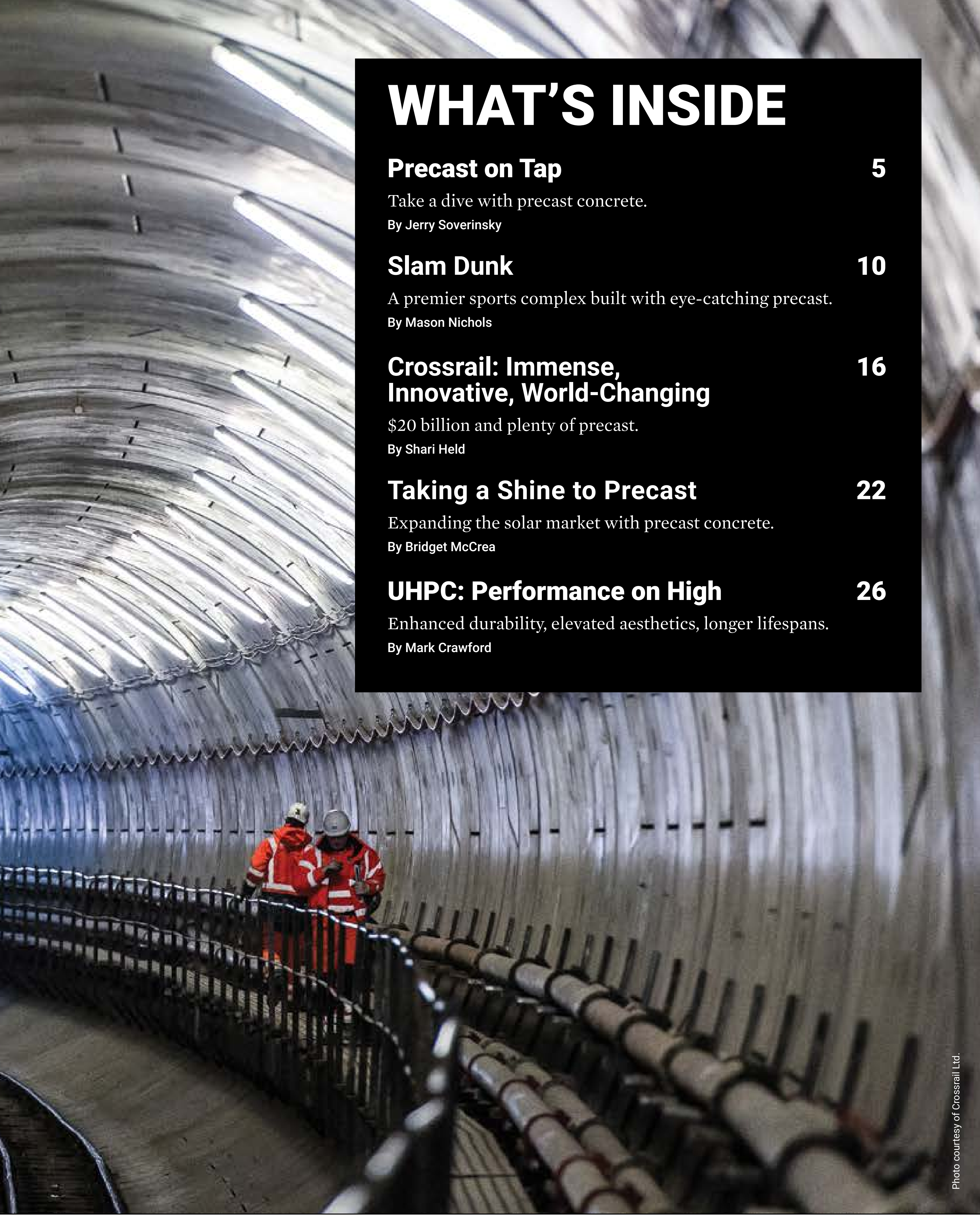


Photo courtesy of Crossrail Ltd.

Precast on Tap

Clever engineering and precise installation anchor impressive project 50 feet below the surface of Lake Michigan.

By Jerry Soverinsky

Photo courtesy of Ballard Marine Construction


Photo courtesy of McMillen Jacobs Associates

Opening a faucet is a lot like magic: Lift a handle, turn a knob or push a button and you have instant access to clean drinking water. It's a benefit that's often taken for granted, and, for many people, what makes it possible is of little consequence. But the engineering that allows water to move from source to drinking glass is anything but ordinary.

For more than a decade, residents of Gary, Ind., and surrounding communities have relied on a water intake crib located approximately 1 mile off the shore of Lake Michigan for potable water. Operated by Indiana-American Water from its Borman Park Treatment Plant, the crib – which is attached to the lakebed – helps deliver nearly 40 million gallons of water each day to area residents.

About 50 feet below the surface of the lake, water enters an 8-foot-diameter vertical shaft that extends down another 150 feet before being passed through a 15,500-foot-long horizontal tunnel. It then travels up to ground level, where it is processed by Indiana-American Water's water treatment facility and distributed to nearly 70,000 customers.

This long journey would not be possible without the crib, which functions as a filter by diverting lake bed sand and sediment away from the intake and preventing larger debris from entering the tunnel. However, the original wooden crib had somehow been damaged, resulting in half the structure being sheared off. As a result, Indiana-American Water commissioned a design-build project in conjunction with McMillen Jacobs Associates and Ballard Marine Construction to provide a new, more resilient crib.

Indiana-American Water tasked the team with finding a solution to the many challenges that face a structure submerged in water. The answer quickly became apparent: precast concrete.

MANY CONSIDERATIONS, ONE IDEAL BUILDING MATERIAL

Although the design-build team initially considered rehabilitating the structure with wood, Grant Horeczy, P.E., senior structural engineer for McMillen Jacobs Associates, explained it wasn't a viable solution for several reasons.

"An important part of this process was the decision to use the existing foundation," he said. "Precast concrete allowed us to use the inherent self-weight of large concrete members to resist wave and impact loads."

Horeczy added precast was also preferable over wood because it doesn't require the use of ballast stone, which is crucial to counteract wood's buoyancy. It's also far easier to remove the lake's ubiquitous zebra mussels – an ongoing nuisance in the area – from precast concrete.

"The zebra mussels in Lake Michigan tend to grow on just about anything," said Trent Nedens, general manager of Midwest operations for Ballard Marine Construction. "But they love things that are porous most of all. So they attach to wood very, very quickly."

Photo courtesy of Wieser Concrete Products

Photo courtesy of Wieser Concrete Products

A dry run conducted at Wieser Concrete's plant in Portage, Wis., helped ensure success for the underwater installation.

Nedens stressed the use of precast would also enable the structure to counteract frazil ice formation, which can occur when water at very low temperatures moves at a high velocity. If frazil ice is allowed to form on the crib, it can choke off the intake, limiting or preventing water from entering the treatment plant in the winter.

"We needed a material that has some of the insulative properties of wood, but with the negative buoyancy of steel, and that's really what led us to precast concrete," he said.

After the design-build team decided on precast concrete, they engineered the new water crib. Horeczy said the final design included a perimeter ring and additional

Divers precisely placed 17 precast pieces underwater to build the water crib.

components that create "table legs" to support a cover over the intake shaft. The team partnered with Wieser Concrete Products of Portage, Wis., to manufacture the 17 precast pieces for the project.

"Precast concrete is easy to install, and if anything ever hits it and damages the structure, the pieces can be easily duplicated since they were made from steel molds," said Mark Wieser, vice president of Wieser Concrete Products.

BENEATH THE SURFACE

The design-build team specified that divers assemble the structure underwater – rather than pre-assembling it and floating it out – due to concrete's physical properties. Thanks to a dry run assembly at Wieser Concrete's plant, the team was well-prepared for the installation, which took place in July. Setting the precast required that divers work 50 feet underwater, placing each piece precisely on top of the existing foundation. To accomplish that, BMC used a self-centering steel jib.

Using surface-supplied equipment, BMC's certified commercial divers performed the installation by working in pairs. Each pair worked 2.5-hour shifts. The divers, who had communication and video equipment attached to their helmets, worked closely with the crane operator and dive supervisor on the surface to ensure all of the individual components were placed correctly. Once the precast units were in proper position, divers employed a series of specialized underwater tools to pull them together. They then secured the water crib to the existing foundation.

Finally, the crew installed PVC piping around the perimeter of the roof, which disperses chlorine into the crib area.

"That helps to deter zebra mussels from growing on the crib as well," Nedens said. "So not only do we have the ability to clean them off the crib very easily, we also have the ability to keep

Photo courtesy of Ballard Marine Construction

them from growing in the first place by dispersing chlorine."

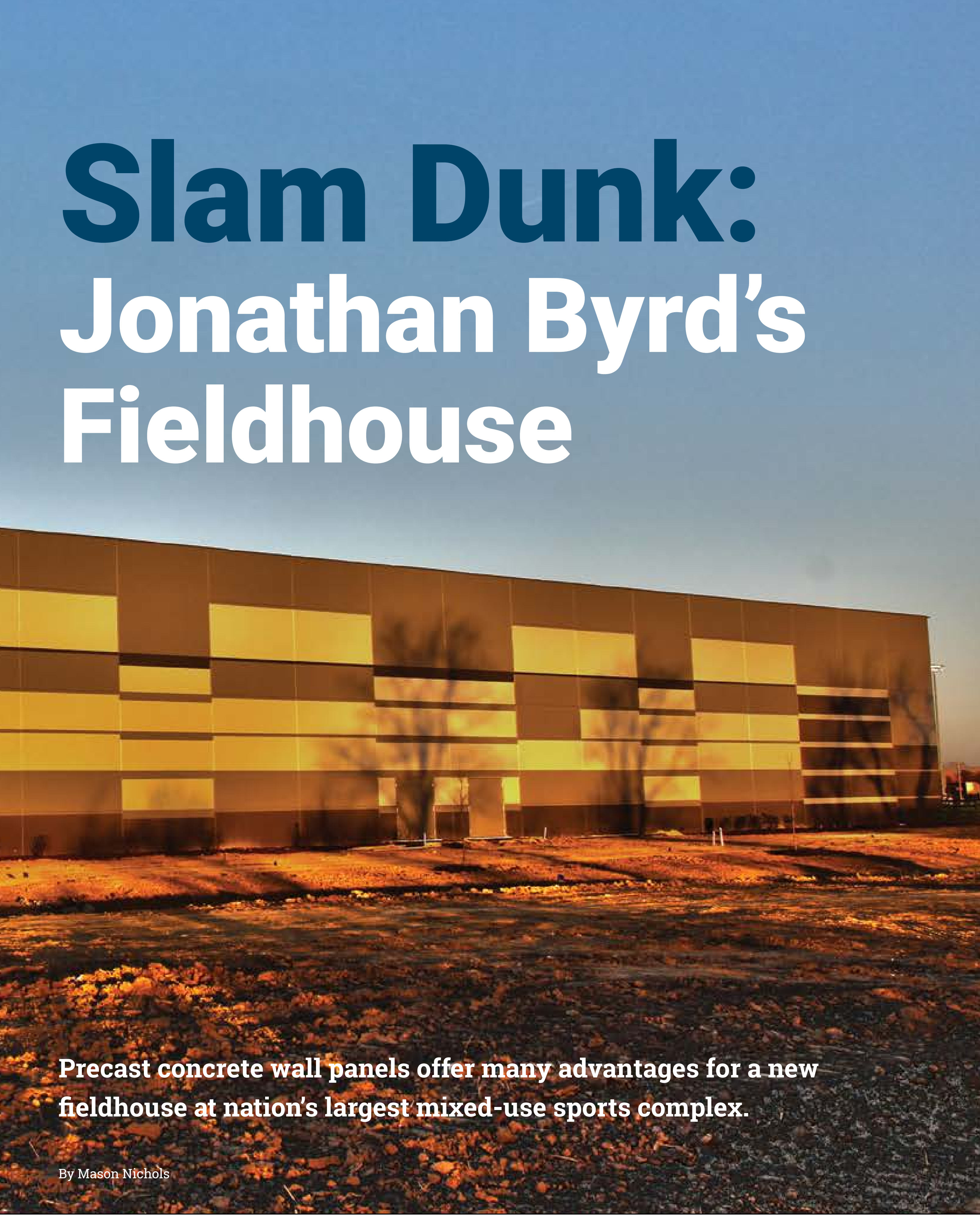
A CLEAR-CUT WINNER

Engineering, designing and installing the water crib may not have been as simple as turning on a faucet, but thanks to the use of precast concrete, residents in northwest Indiana can continue to enjoy the benefits of clean drinking water for years to come.

"Precast concrete was a clear-cut winner among the alternatives explored," Horeczy said. "Simply put, it allowed us to easily make the shapes we desired with a quality that could be verified prior to installation." PS

Jerry Soverinsky is a freelance writer and journalist who covers more than a dozen industries.

Slam Dunk: Jonathan Byrd's Fieldhouse



Precast concrete wall panels offer many advantages for a new fieldhouse at nation's largest mixed-use sports complex.

By Mason Nichols

Workers pieced together nearly 100 load-bearing precast concrete panels to construct Jonathan Byrd's Fieldhouse.

Just north of Indianapolis, a massive, 400-acre sports park offers more than 50 fields for recreational sports ranging from soccer to baseball and everything in between.[1] But the plans for Grand Park, which opened in June 2014, extend even further. In the future, the largest U.S. mixed-use sports complex will also feature a variety of dining, retail and entertainment venues, making it a centralized hub for youth sports in the Midwest.

For now, the park continues to expand with the construction of indoor recreational facilities. In January, Grand Park opened Jonathan Byrd's Fieldhouse, an 88,000-square-foot structure housing eight courts mainly for basketball and volleyball games. Specifiers turned to precast concrete to meet the project's tight schedule and provide a durable, attractive building envelope.

A HAPPY MARRIAGE

City officials envisioned a structure that would be as pleasing to the eye as it would be functional. After consulting with American Structurepoint, the project's architecture and engineering firm, both parties agreed to erect the fieldhouse with architectural precast concrete wall panels.

Dan McCloskey, senior project architect for American Structurepoint, explained why precast panels provided the ideal solution.

"Precast concrete was a great material to marry aesthetic options with ease of construction," he said. "The ability to cast in reveals and varying profiles while working with the precast supplier to fine-tune the structural life of the panel and the

exterior face details was a smooth process."

American Structurepoint collaborated with Coreslab Structures, the precast supplier, to develop three distinct panel designs with varying reveal patterns. The three templates were interchanged among the 94 precast panels installed, giving the fieldhouse a unique appearance.

According to Mark Greiner, sales consultant with Coreslab, the 32-foot-tall, 10-inch-thick panels are load-bearing. As a result, no interior columns support the

Thanks to a dynamic three-tone paint scheme, the fieldhouse packs a visual punch.

structure. Instead, the panels are braced, relying on the roof to hold them in place.

WINNING BIG WITH PRECAST

A compressed schedule mandated efficiency from the moment developer and general contractor Lauth Construction broke ground on the project. Crews had limited time to fully enclose the building, at which point the interior finish work – including laying down the courts and placing the bleachers – could be completed.

"When Lauth got the project, the schedule was very important," Greiner said. "They really had to get these panels engineered, fabricated, delivered and erected in a pretty rapid timeframe."

Thanks to the solid relationships built among the parties involved, Coreslab was able to manufacture and ship the panels to the site in less than four months. With the panels on site, construction hastened. Chris Vensel, Lauth's director of pre-construction, noted precast was crucial to getting the structure up on time.

"Using precast enabled an accelerated installation," he said. "We completed all of the [on-site] precast work in less than 10 working days."

Besides offering a shortened timeline, the use of precast also increases the fieldhouse's durability. Outside, precast enables an extended service life, protecting the structure from the elements. Inside, the walls can endure heavy usage as the facility operates over the years.

CROWD-PLEASER

Basic building shells can lack charisma, but the completed Jonathan Byrd's Fieldhouse packs plenty of visual punch. In addition to the aforementioned reveal patterns, the structure features a distinctive three-tone paint scheme. The result is a building that captures plenty of attention for its architectural flare.

"The fieldhouse meets and exceeds what the owners were looking for on the project," Greiner said. "It's very modern, the paint scheme is colorful and it's certainly a building that will be noticed."

McCloskey agreed, noting Coreslab fabricated the panels with extreme precision.

"Those reveal lines are about as straight as I could ever possibly imagine them being," he said. "When the colors were added, it began to sing from the standpoint of the aesthetic. It turned out as well as it could have."

NO COMPETITION

To build a premier sports complex deserving of the name "Grand Park," top-notch building materials must be used. In the case of Jonathan Byrd's Fieldhouse, precast concrete delivered.

"I don't even know what other product we would have thought to use," McCloskey said.

While the results of the sporting events inside will be unpredictable, participants and attendees alike can count on the durability and attractive design of Jonathan Byrd's Fieldhouse for decades to come. PS

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

Endnotes

[1] ibj.com/articles/42374-westfield-s-sports-plan-is-grand

Photo courtesy of Tony Frederick Photography

Crossrail:
Immense, Inno
World-Changin

Photo courtesy of Crossrail Ltd.

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A variety of precast concrete products play a crucial role in the construction of Europe's largest infrastructure project.

By Shari Held

Rows of precast concrete segments await transport at Chatham Dockyard.

As the largest infrastructure project in Europe, Crossrail is an endeavor that's decades in the making. During its construction, Londoners go about their day-to-day business unfazed. But 130 feet below the 2,000-year-old city, a cast of thousands quietly works to complete the world-changing project.

In all, Crossrail consists of 26 miles of new tunnels for the Crossrail/Elizabeth line. Once fully operational in 2019, the new line will connect commuters to the London Underground and National Rail, allowing them to leave their cars at home and travel all the way across London and beyond. Reduced motor traffic will greatly benefit London motorists, who spend 12 working days per year sitting in gridlocked traffic.[1]

Forty railway stations – 10 of them new – are included in this gargantuan, $19.6 billion project. And precast concrete plays a key role in the construction of the project's numerous tunnels, platforms and stations.

In many ways, Crossrail is a project of numbers. It employs 10,000 workers located at 40 sites throughout London. Each tunnel-boring machine weighs 1,000 tons. And during the tunneling phase, those TBMs moved 7.5 million tons of earth to make way for the 15-billion-ton railway. But Linda Miller, project manager for the Connaught Tunnel and Farringdon Station, thinks one particular statistic stands out from the rest.

"My favorite number is that it's going to create 200 million more passenger journeys per year," she said. "That's gobsmacking!"

SETTING THE STAGE

Crossrail Limited, the company established to build the new railway line, went to great lengths to ensure the project's success. Early on, Crossrail Ltd. gathered experts from throughout the world and pioneered innovative technologies to tackle potential issues.

The biggest obstacle to project approval was the fear that tunneling would damage London's existing structures and infrastructure. To mitigate potential damage, Crossrail Ltd. positioned thousands of movement-detecting prisms on buildings throughout London. The prisms relayed terabytes of information that Crossrail Ltd.'s state-of-the-art data center analyzed. The data was then provided daily to project managers.

"We knew if the ground or a building was moving within 1 to 3 millimeters," Miller said.

Crossrail Ltd. took proactive measures to ensure it could correct those situations on the fly. Workers assembled 25 composition-grouting shafts measuring 16 or 20 feet in diameter and 65 feet deep next to the route before tunneling began. If an area showed signs of settling, they pumped grout into the shaft to gently lift the ground. The strategy paid off.

"We didn't tip any buildings," Miller said. "We didn't create any exploding utilities. We didn't – even by a millimeter – affect the running of the current London underground tube systems."

LINING THE TUNNELS

Eight TBMs and 210,000 precast segments were required to line the 26 miles of tunnels necessary for the project. Seven segments, each weighing approximately 6,600 pounds, and one keystone weighing about 2,200 pounds make up one tunnel ring. Typically, the segments were reinforced with steel fiber. Steel rebar was used for sections located under bridge abutments and floating slab track.

"With precast, you get a much higher quality of product," said Andrew Thomas, Crossrail Ltd. quality engineer. "You control it a lot better by manufacturing off site. I don't think anything else would have been as successful as precast."

To meet the demand for such large quantities of precast, Crossrail Ltd. created three factories that operated around the clock.

"We needed to make sure that all the mixes that were designed were robust enough and durable enough to last 120 years in quite a corrosive environment," Thomas said.

Polypropylene fibers were also used to give the precast increased resistance to spalling under fire conditions.

TUNNELING 130 FEET UNDERGROUND

Tunneling began in May 2012 and ended in June 2015. The TBMs tunneled about 328 feet per week. The process was methodical. Locomotives transported the precast segments and keystones into the tunnel, where they were loaded into the TBM's "belly." The TBM's cutter head then bored through the earth, depositing the soil above ground via a conveyer system. When the TBM cleared enough space to construct a ring, its robotic arms positioned the precast segments. Workers then bolted them together using hydraulic drills. Once a ring was complete, the TBM propelled forward to begin boring for the next ring.

While tunnel boring is typically straightforward, difficulties can occur. This was the case for the

Eight massive tunnel boring machines cleared the way for the 26 miles of tunnels required for the project.

Photo courtesy of Crossrail Ltd.

Connaught Tunnel, which runs under the Royal Dock. Connaught Tunnel opened in 1878 and hadn't been in service since 2006.

"When we first met the Connaught Tunnel, it was completely deserted and overfilled with high grass and weeds," Miller said.

Workers widened and deepened the tunnel to accommodate modern, full-sized trains. But Miller hadn't planned on having to build a cofferdam to pump out more than 3 million gallons of water.

"We were very proud to be the team that breathed life back into the Connaught Tunnel as part of Crossrail," he said.

PRACTICALITY AND AESTHETICS

Once tunneling was complete, focus turned to the stations. The existing 30 stations were located above ground. Five of the 10 new stations, including Farringdon, were mined underground structures. For these stations, glass fiber reinforced precast concrete was used for the internal cladding.

When it opens, Farringdon Station will be one of the most important transportation hubs in central London. Its public areas are clad with a sophisticated design crafted from disc-shaped GFRC panels. Some segments are single-curved while others are double-curved. These curved edges help reduce blind spots and enhance passenger navigation.

Netherlands-based Sorba supplied the precast concrete for Farringdon. Each station had its own suppliers since all stations were constructed simultaneously.

"It was quite a challenge to get all the concrete we needed at the correct time and with the correct quality," Thomas said. "We achieved it, but it certainly took a lot of collaborative effort."

The mix used to form the panels contains a special plasticizer that gives the concrete a consistency like chewing gum. Within 20 minutes, a skin forms on the surface, acting as a mold for the mix. This allows the mold to be manipulated over a steel arched form and secured in place until the concrete is strong enough to hold its shape. Once fabricators achieve the correct consistency, they begin creating the curved precast shapes.

All of the tunnels have common characteristics to keep a passenger's journey consistent. But once a passenger rides up the escalator to the station's entrance, consistency transitions to the unique. Every station is designed to reflect the characteristics of its environment.

For example, Farringdon's eastern ticket hall features metal

Architectural renderings depict Farringdon Station's public areas, which are clad with disc-shaped GFRC panels.

sliding-screen gates. This serves as a nod to watchmakers, goldsmiths, ironmongers and blacksmiths, and the Brutalist architecture of the nearby Barbican Centre. The western ticket hall pays tribute to Hatton Garden, the center of the U.K.'s diamond trade. Its ceiling was built using white, reflective, diamond-shaped precast concrete segments.

"That's something we could only really do with precast," Thomas said.

Precast was selected for its acoustic properties as well as its architectural aesthetic. Sophisticated computer modeling was employed to test how the public address and voice alarm speakers would interact with the station.

After "many iterations," designers discovered that precision holes located in specific places in the discs produced the desired acoustic properties.

Prior to Crossrail, GFRC had not typically been used for rail stations.

"We've shown what a fantastic material it is with regards to acoustics, light reflectance and aesthetics," Thomas said. "It will definitely be used for future U.K. construction projects."

JOURNEY'S END

Although Crossrail isn't quite complete, it's already considered a huge success. And it's still on track for meeting its original schedule.

The project sets new industry standards, notably in the area of used technologies, which other transport networks are adopting. Strategic planning, cutting-edge equipment and innovative materials – including precast concrete – were undeniably important to the project's success.

"All those kinds of things pull together to make us feel bloomin' proud," Miller said. "I've never felt so inspired than in the incredible work that Crossrail Ltd. has done." **PS**

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

Endnotes

[1] businessinsider.com/traffic-congestion-in-london-2015-8


Photo courtesy of Megan O'Leary Photography

Taking a Shine to Precast

On track to grow by 119% in 2016, the solar industry is incorporating more precast concrete into its innovative projects around the U.S.

By Bridget McCrea

Dalmaray Concrete Products of Janesville, Wis., manufactured more than 1,500 precast footings for the Rock River Solar Project.

The U.S. solar market is in the middle of a growth spurt, and it's pulling the precast concrete industry right along with it. According to the Solar Energy Industries Association, the market is expected to grow by 119% this year. Installations are set to reach 16 gigawatts – more than double the record-breaking 7.3 GW installed in 2015.[1]

Much of that growth will be driven by utility-scale installations, with residential and commercial projects also on track for strong growth in 2016. During the first quarter of this year alone, 1,665 megawatts of solar photovoltaic projects were installed in the U.S., with the solar industry adding more capacity than the coal, natural gas and nuclear industries combined.

SEIA reports there's an "enormous amount of capacity in the pipeline," with more than 53.3 GW of photovoltaic and concentrated solar power projects either under construction or under development.

Precast concrete has already made a name for itself on a few large solar projects in the U.S., so if past history is any indication, owners may look to incorporate more of it moving forward. And, if the precasters involved with these projects have their way, that trend will persist as the solar market continues to expand in 2016 and beyond.

THE ONLY OPTION

As momentum in the U.S. solar market continues to build – and as more engineers and specifiers explore the value that precast offers for these initiatives – expect to see more precasters getting involved with eco-friendly energy projects.

"When you start to talk to specifiers and engineers about precast's strengths, including the speed of manufacture and installation, quality of product and the fact that projects can be completed in the dead of winter," said Aaron Ausen, vice president at Dalmaray Concrete Products in Janesville, Wis., "they really take a shine to it."

Ausen said Dalmaray secured its first major solar endeavor after reading about a solar field project in Beloit, Wis., last year. Thanks to a good working relationship with Alliant Energy, the local utility company, he connected with the engineering team to learn more. The team had not considered precast, and the project was grappling with an unresolved issue and had been temporarily "mothballed" due to that hurdle.

"When the project fired back up again, Alliant Energy knew what it wanted to do but didn't really know how to get there," said Ausen, who noted that the utility company had previously used precast on a single, small-scale project. That project was successful, but wasn't of the same scale or magnitude as the new project. To get precast's selling points across to the customer, Ausen developed a two-page document outlining why precast was a better solution than cast-in-place concrete.

"That really opened their eyes to the benefits of precast and pushed them to dive a little further into it," he said.

For the Rock River Solar Project, Alliant Energy planned to install solar tracker pads on top of a capped landfill in Wisconsin. The utility company and its partner, Korean solar energy firm Hanwha Q CELLS USA, had to meticulously engineer the structures that hold the solar arrays, because state law does not allow landfill soil to be disturbed.

Because the landfill contains a liner buried two feet below grade, the typical solution of driving I-beams into the ground was not possible. In addition, the project called for a winter installation. Dalmaray's custom precast solution minimized concerns and offered benefits no other alternative could provide.

"Precast was the only option at this time of year," said Mark Miller, senior manager-estimating and pre-construction services for civil contractor Michels Corp. "Having the ballast blocks cast in a temperature-controlled environment and shipped to the site enabled the work to be completed in the winter."

SPEED AND FLEXIBILITY

Dalmaray's flexibility was paramount to the success of the project. Each time Alliant Energy changed its plans – be it the connections, bolts or any another component – the precaster reacted quickly, altering the design without adding time or complexities to the project.

"Through that process, the customer came to understand the full gamut of precast's benefits and just how agile and flexible it can be on a major project like this," Ausen said.

For example, project engineers originally specified I-beams that supported the concrete panels. The beams were to be cast on site, but when Ausen learned that those pieces had to be installed within one degree of tolerance – on ground that wasn't perfectly level – he came up with a better alternative.

"We embedded the I-beam with a floating, 1-inch steel plate mounted on anchor bolts," he said. "This allowed the plumbness to be adjusted and for that very tight tolerance to be achieved."


Photo courtesy of Megan O'Leary Photography

In addition to the 1,659 precast footings, Dalmaray manufactured many smaller precast items at the customer's request.

"We kind of wound up turning into the Walmart of precast," Ausen said. "With everyone coming to us asking us to produce different pieces for them, our answer was always, 'Sure, we can do that. No problem.'"

Looking back, Ausen calls the Rock River Solar Project the "biggest and best" the company has ever done and added that Dalmaray is looking forward to working on more solar initiatives in the future.

"It was definitely a turning point for our company," he said. "In fact, we just got a call yesterday about a new solar project in Illinois. They want us to come and look at the design and lend our expertise to the project."

PUTTING PRECAST ON THE MAP

Elsewhere in the Midwest, Lindsay Precast of Canal Fulton, Ohio, sprang into action and developed a custom solution to help a customer who needed a concrete pad developed for its solar power inverter stations in Maryland.

"They were looking at different options and came to us for help," said Lynn

Lindsay Precast's plant in Canal Fulton, Ohio, delivered custom precast concrete solar pads for a project in Maryland.

Grimm, specialty projects manager. "We enjoy custom work, so we brainstormed with their engineers to come up with a workable design for the project."

For the pads, the customer sought a solution that would be more durable and cost-effective than steel. They were also looking for a material that would eliminate the need for cast-in-place foundations on some sites. The answer was precast concrete.

The project required custom design work and precise engineering due to the complexity of the equipment it supports. Features cast into the solar skids included conduit for 120/240 volt and data connections, a 4/0 copper ground loop with stainless steel landing plates for field grounding connections and stainless weld plates. The weld plates anchor the control station and the power panel components as well as a site-installed canopy. The slab also has cast-in cable tray grooves for running the large AC power cables with inserts for attaching and sealing the aluminum cable tray covers.

"Each solar skid includes custom components, and we were able to adjust as the project progressed because we have our own on-site fabrication division," Grimm said. "It was all tailored to the job by specifics, and depending on what each solar skid included."

In the field, the pads help facilitate a complex process that converts the sun's rays into usable energy for the power grid. Wires combine the DC electricity from the solar panels and send to the hardware fixed to the precast pad, where it is converted it to AC electricity. The AC electricity runs through nine, 1 1/4-inch diameter cables connected to the low voltage side of the transformer using the grooves in the pad. Lastly, the medium voltage side of the transformer transfers the electricity to the grid for use.

According to Grimm, the solar power inverter station project was successful and the company is already working on several new solar initiatives.

"Like many other industries looking to achieve high levels of quality and cut down the on-site installation time, the solar industry is definitely headed in the direction of using prefabricated materials," she said. "We're still working to get the word out to designers and customers about this, as many of them don't even know about the grand possibilities of precast. Going forward, we'll continue working to get our industry on the map in solar construction."

A BRIGHT FUTURE

As the amount of solar work in the U.S. continues to rise, project owners are in ever-increasing need of a high-quality building material that meets the multi-faceted needs of the industry. Precast concrete producers stand ready to provide solutions that are durable, easy to install and customizable for nearly any situation. **PS**

Bridget McCrea is a freelance writer who covers manufacturing, industry and technology. She is a winner of the Florida Magazine Association's Gold Award for best trade-technical feature statewide.

Endnotes

[1] seia.org/news/us-solar-market-set-grow-119-2016-installations-reach-16-gw

UHPC: Performance on High

With its unique qualities, ultra high performance concrete provides flexibility and flare for precast projects.

By Mark Crawford

For specialized projects, a growing number of owners and builders want more from their concrete – more strength, more durability, more ductility and more moldable shapes. The solution for these performance needs is often ultra high performance concrete.

According to the Portland Cement Association, UHPC is a "high-strength, highly durable, ductile material formulated by combining portland cement, silica fume, quartz flour, fine silica sand, high-range water reducer, water and steel or organic fibers."[1] The material provides compressive strengths from 17,000 to 29,000 psi and flexural strengths up to 7,000 psi. UHPC's superior durability characteristics are a result of the fine grain size (maximum 600 micrometers) and chemical reactivity. The net effect is maximum compactness and a small, disconnected pore structure.

Thanks to these impressive strengths, UHPC can resist bending and withstand major transformations, such as pressure or dilation, without breaking.

"Also, being resistant to external influences such as abrasion, pollution, weathering and scratching, UHPC will last two or three times longer than conventional concrete," said Brent Dezember, president of StructureCast in Bakersfield, Calif.

These attributes make UHPC a desirable material for major construction and civil engineering projects, especially those employing precast concrete.

MORE DESIGN OPTIONS

UHPC makes it easier for engineers and architects to create complex geometric forms, such as curved canopies. As a result, UHPC is often the material of choice for decorative facades and surfaces. Additionally, because it is both aesthetically pleasing and resistant to the elements, it's highly suitable for bridge or tunnel construction. UHPC's superior durability and impermeability against corrosion, abrasion and impact also result in less maintenance and longer lifespans.

Ductal – Lafarge's UHPC solution – even exhibits self-healing properties.

"The cement is used as an aggregate as well as a binding agent," said Don Zakariasen, director of marketing for concrete products for Lafarge in Calgary, Alberta. "If a crack occurs and water migrates into the structure, the cement is reactivated and a bond is re-developed across the crack."

Photo courtesy of Lafarge

UHPC played a key role in achieving the specified aesthetic for the Innovation Centre for Engineering at the University of Alberta in Calgary.

By using UHPC, thinner form factors can be achieved, reducing a structure's overall weight.

UHPC flows much like a clay mixture, but due to its sheer mass, it finds level and fills every void in the mold with amazing density. This makes it an ideal material for replicating fine details in architectural concrete applications.

"We once cast a series of panels and had what appeared to be some stress cracking in the face of a few of them," Dezember said. "The marks turned out to be a human hair that was partially sanded in our mold material. Ductal's finished surface can be as smooth as glass and it takes on all the properties of the mold."

UHPC can also be used to lighten the overall weight of structures with thinner form factors, thereby requiring little or no passive reinforcement for most applications. This enables time and cost savings across many links in the value chain, including the reduction in quantity of materials used and faster construction through prefabrication, transportation and construction.

"By utilizing UHPC's unique combination of properties, designers can create thinner sections and longer spans that are lighter, more graceful and innovative in geometry and form while providing improved durability and impermeability against external elements," Dezember added.

A FEW CONSIDERATIONS

With its many unique characteristics, UHPC is an ideal fit for specific types of precast concrete work. In most cases, it's reserved for projects that cannot be constructed using regular concrete. According to Zakariasen, the drivers for using UHPC are strength, weight limitations, finish and durability.

UHPC is generally more expensive than standard concrete. Still, it can be the most economical solution for some projects.

"Cost must be considered from a project total in place of cost perspective, which captures the entire picture, with all the interfaces from other trades and the overall schedule," Zakariasen said. "The best approach is for the precaster to make a high-level decision whether UHPC can be a potential solution and, if so, to provide budget pricing."

Daniel Thompson, professional engineer with Gate Precast Concrete of Ashland, Tenn., stressed the importance of considering UHPC early in the design process to achieve success. He added that UHPC is an excellent choice for structural columns and beams and odd-shaped panels.

UHPC IN ACTION

Lafarge has used Ductal for pedestrian overpasses, architectural building cladding projects and a unique light-rail transit station canopy system.

"We have also successfully replaced stainless steel troughs in sewage treatment with UHPC," Zakariasen said.

StructureCast manufactured precast components with UHPC on several challenging projects, including its Capilano View Cemetery Columbaria Roof Panel project in West Vancouver, B.C. The panels were required to span 17 feet in a region with significant snow loads and ice while maintaining a minimal profile. With a compressive strength of up to 25,000 psi and flexural strengths up to 6,000 psi, the system was strong enough to support the long span.

The roof consisted of six precast panels, each weighing 2,200 pounds. The underside of each panel was cast down in a mold made of wood and coated in a special polyurethane enamel, which

UHPC is an ideal material for replicating fine details in architectural concrete applications.

StructureCast of Bakersfield, Calif., cast UHPC panels with a compressive strength of up to 25,000 psi for these columbaria roof panels.

Photo courtesy of Eric Taylor Photography

The St. Elizabeths East Gateway Pavilion in Washington, D.C., was constructed with a striking UHPC roof.

allowed the UHPC to exhibit a marble-like shine. The top side of the panel was hand-finished.

The cost of the six Ductal panels was nearly half of a stainless steel roof system similar in shape. Another advantage to the UHPC roof panels was their light weight – a conventional concrete roof would have weighed 4,000 to 6,000 pounds more.

"The panels were cast in seven days using one mold. The ability to use just one form cut down on both material and labor forming costs. From order to delivery, the project was completed in less than 30 days."

The University of Alberta in Calgary recently completed its new Innovation Centre for Engineering. The exterior finish is a creative blend of glass, metal and precast concrete. One of the most striking features is the "fly-by" building cladding system on the corners of the structure. The transparency of the glass and the minimal impact of the supporting structure make this feature unique.

UHPC was the key element that made these architectural features possible. The surface finish was designed to generate the appropriate level of shadows while still naturally shedding dust and grime. Lafarge provided 590 Ductal precast concrete elements of multiple heights and lengths, with thicknesses varying from 17 to 35 millimeters, to create the architectural effect. Mountings were designed to allow connection into the vertical mullions within the glass curtain wall system. The fly-by corners used the precast as the structural element to carry gravity, wind and seismic loads and distribute these loads over multiple mullions within the curtain wall system.

"The end result is a striking introduction of horizontal features, which reduces the verticality of the building, combined with unique corner features that have never been accomplished before," Zakariasen said.

THE NEXT LEVEL

For projects where enhanced durability, elevated aesthetics and longer lifespans are needed, ultra high performance precast concrete products are an ideal solution. And as the impressive material continues to evolve, it will play an even more significant role in taking the architecture, engineering and construction industries to the next level. PS

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

Endnotes

[1] cement.org/for-concrete-books-learning/concrete-technology/concrete-design-production/ultra-high-performance-concrete

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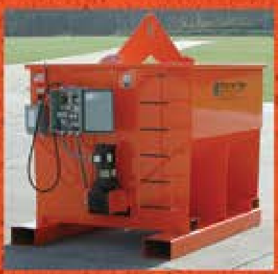

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