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FALL 2014

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Photo courtesy of Tom Harper Photography 16

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In style: For Weber Design Group of Naples, Florida, the use of precast concrete is integral in the design of luxurious homes with equal parts durability and aesthetic flare. Learn more about the application of precast products for a variety of high-end projects by reading the story on page 16. Photo courtesy of Giovanni Photography.

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Precast ... The Concrete Solution

Strength to a Double Tee

Structural engineers hold a load testing event in Colorado to assess the strength of precast concrete double tees.

By Evan Gurley and Kayla Hanson

What happens when 4,400-lb highway barriers are placed on top of a 10-ft-wide, 60-ft-long precast, prestressed concrete double tee? Engineers, precasters and students alike gathered in April 2014 at Colorado Precast Concrete in Loveland, Colorado, to find out.

What is a double tee?

Like the name implies, a precast, prestressed double tee resembles two side-by-side capital letter Ts. The two vertical leg sections are called webs or stems and the horizontal section is known as the deck or flange. Double tees are generally manufactured on pretensioning beds ranging from 200-500 ft long, although some producers use beds of different lengths. Beds are manufactured in the same orientation as double tees are to be installed in the field (the stems and lower surfaces of the flange are form finished and the top surface is finished manually).

Prestressing tendons are situated in the forms and are stressed prior to casting. These tendons consist of high tensile strength cables, typically of multiple strands. Each double tee's flange is cantilevered

Despite nearly 90,000 pounds of highway barrier resting on its surface, the double tee held together.

from the stem. Conventional reinforcing steel is then placed in the flange to resist tensile stresses. The reinforcing steel also helps resist flexural stresses from out-of-plane loads and provides protection from drying shrinkage cracking.

After the concrete cast into the forms reaches a specified compressive strength, the tendon ends are cut, placing the stems in compression. This compression shortens the lower section of double tee, resulting in upward camber, which counteracts dead loads, live loads and creep deflection.

Once the double tees are welded together, the double tee joints are treated and, if applicable, toppings are applied. Waterproofing membranes can also be used to protect the double tee from water penetration.

Double tees offer plenty of flexibility in design and construction, where they are an ideal choice for structures requiring long, uninterrupted spans and high load carrying capabilities. The design of a prestressed double tee allows the deck to act integrally with the superstructure, as prestressed double tees have a monolithic deck and stem design. The integral design provides a stiffer member, while the material-saving shape reduces the dead load. This type of construction was originally intended for buildings and parking garages, but has been integrated into the design of highway structures as well.

Typical dimensions of prestressed double tees are:

- Stem depth: 12-34 in. (up to 5 ft)
- Flange width: 8-10 ft (up to 15 ft)
- Span length: 25-55 ft (up to 80 ft or more)

Under pressure

On April 17, 2014, the northern division of the Structural Engineers Association of Colorado hosted a double tee load test event at Colorado Precast Concrete in Loveland, Colorado. A full-size 10DT24+2 double tee (see "Decoding the double tee") designed for a typical parking garage floor member was load tested to determine performance. Stresscon of Colorado Springs supplied the 10-ft-wide, 60-ft-long double tee for the demonstration.

Decoding the double tee

10DT24+2

10 – Width of precast section (ft)

DT – Description of section (in this case, "DT" means Double Tee)

24 – Depth of precast section (in.)

+2 – Topping

The double tee was loaded to service level, 85%, ultimate, 110% and failure. Testing procedures closely followed those found in Chapter 20 of ACI 318, "Building Code Requirements for Structural Concrete," except for the 24-hour applied load time and the response measurement, which were a result of time restrictions.

The objective of the testing was to determine the structural performance of a common double tee designed for a typical parking garage floor member while showing deflection and rebound. The double

PHASE AND LOAD TYPE	NUMBER OF BARRIERS	DEAD LOAD	LIVE LOAD	PROJECTED MOMENT	ACTUAL MOMENT	CHANGE IN DEFLECTION	TOTAL DEFLECTION
1 Typical Condition	4	8 psf	30 psf	534 kip·ft	493 kip·ft	N/A	0.03″
2 Code Level Service	7	8 psf	40 psf	580 kip·ft*	597 kip·ft**	0.80″	0.83″
3 85% of Ultimate	9	8 psf	40 psf	654 kip·ft	653 kip·ft	1.26″	2.09″
4 100% of Ultimate	11	8 psf	40 psf	769 kip·ft	768 kip·ft	2.84″	4.93″
5 110% of Ultimate	12	8 psf	40 psf	846 kip·ft*	830 kip·ft**	1.61″	6.54″

Table 1 – 10DT24+2 Load Test Results

*The Projected Moment is due to loads indicated in the loading diagrams available at precast.org/loadtest.

**The Actual Moment is due to test loading.

tee was loaded with 4,400-lb highway barriers for the five different loading phases, where the factored service load was determined to be 29,300 lbs. Barriers were loaded on the double tees with weights corresponding to the five different phases.

When loading the double tee at 85% of ultimate, 1 in. of deflection and 1 in. of rebound was recorded when barriers were removed. Test results showed the resiliency and the safety factor engineered into the design of the precast member. The double tee finally reached the failure phase when 20 barriers (88,000 lbs) were loaded, causing the double tee to deflect more than 44 in. and touch the ground. Although it was deemed failed, the double tee still held together despite nearly triple the calculated service load resting on the surface.

Tee time

Today, double tees are an ideal solution for projects involving bridges, parking decks, flooring and roofing systems, industrial buildings and more. No matter what the application, double tees are spanning longer distances and performing at higher levels than ever before. PS

Evan Gurley and Kayla Hanson are technical services engineers with NPCA.

All photos courtesy of NPCA staff.

Want to see the load test in action? Visit precast.org/loadtestvid

Double Tee Advantages

Precast, prestressed concrete double tees offer many advantages, making them suitable for construction of elevated parking decks as well as the substrate for waterproofing, roofing systems and buildings. The combination of robust reinforcing steel and the depth of the legs/stems allows the double tee to support loads over long spans. With their efficient cross section and high section modulus, precast double tees have been designed to span 80 ft or more.

Additional advantages include:

- Low initial project cost and little maintenance throughout the life of the product.
- Faster fabrication and erection, speeding up the construction process compared to cast-in-place structures.
- Higher durability and sound resistance, including the ability to withstand wind, road salt, earthquakes and even fire.
- A column-free solution.
- Simplified frame, design and construction.
- Openings for service pipes/ducts incorporated.
- Use of precast elements in frame is possible.

References

ACI 318 – Building Code Requirements for Structural Concrete

A *Sweet* and Serious Business

When a big steel storage tank blew its rivets in 1919, Boston harbor residents, horses and buildings were inundated by a huge wave of molasses. This major port disaster led to better tank inspections and safer designs, as can be seen in today's precast storage tanks.

By Sue McCraven

Preconco Limited's precast concrete molasses storage tanks offer a combined capacity of more than 35,000 tons.

Gingerbread man cookies, brown sugar, citric acid and a good rum cocktail. What do these products have in common? They all contain a sweet fluid made predominantly from processing sugar cane: molasses. Molasses is an important commodity; however, if improperly stored, it can be bad news (see sidebar "Boston Molasses Disaster & Hawaiian Spill"). Safely containing molasses is serious business, but thankfully, durable precast concrete storage tanks are up to the task.

Aging steel

In the Caribbean, Preconco Limited entered into an atypical public-private partnership with the government to build three new precast concrete molasses storage tanks with a capacity of more than 35,000 tons. The need for durable, strong storage for molasses had become a critical concern for the island's controlling authorities because the three aging steel storage tanks in the port city had become structurally unsound.

"The first steel tank was in such a deplorable state that it was unserviceable based on all of the technical data," said David Estwick, Barbados Minister of Agriculture, Food, Fisheries and Water Resource Management.[1] Officials reasoned that the other two steel tanks were in similar states of deterioration.

Long-term storage solution

Construction of the precast concrete storage tanks is critical to sustain the Caribbean's rum industry, as molasses is imported and stored in port facilities. With rum being a major Caribbean export, the

Boston Molasses Disaster & Hawaiian Spill

Molasses may be sweet, but it is not always innocuous. In 1919, residents of Boston's harbor district heard the frightening, machine gun-like sound of popping rivets. Moments later, a 15-ft high, 2.5-million gallon wave of Puerto Rican molasses exploded out of a huge, 50-ft high steel tank that demolished buildings and killed anything alive in its sticky swath. Twenty-one people lost their lives in Boston's North End that unseasonably warm January day.

The ensuing six-year long lawsuit against the tank owner, United States Industrial Alcohol Company, led to a noted MIT engineer[3] determining that poor construction led to the tank's collapse. As a result, state laws were enacted to require an engineer's inspection of tanks.

In 2013, a similar disaster occurred in Hawaii when a pipeline carrying molasses from Oahu to cargo ships released 233,000 gallons into the waters of Honolulu Bay, not far from Pearl Harbor. This time, molasses created an environmental disaster that killed large numbers of marine life. Because there is no method for remediation,[4] scientists said the only thing to do now is wait for natural forces to run their course.

Barbados Rum Committee heartedly supported the new storage tank construction.

"Without a storage facility at the Bridgetown Port to take imported molasses, we will have no rum industry," said Chairman of the Barbados Rum Committee Frank Ward.

Preconco partnered with Britain's Structural Systems Ltd. for design of the post-tensioned vertical panels that comprise the circular tank. Preconco designed the vertical panels and the tank foundation and is the installer of all three tanks.[2] The company was also contracted to tear down the existing steel storage tanks.

Mark Maloney, CEO of Preconco, said he expects the third tank to be completed by early 2015. "Under the lease agreement, we will maintain all three tanks for their service design of 50 to 75 years," he said.

No more flooding!

Plans called for Preconco to design and build two precast concrete molasses storage tanks with more than 13,000-ton capacity and one tank at nearly 9,000-ton capacity. The tanks range between 84 and 102 ft in diameter with a height of 23 ft. In addition to post-tensioned precast walls and post-tensioned cast-in-place (CIP) foundations, the company fabricated the roof, internal epoxy lining, piping inlets and outlets, measurement system and access ladder with roof handrails.

The client, Barbados Agricultural Management Co., selected a precast concrete tank design for long-term durability, low maintenance costs and the material's increased ability to withstand marine environments over steel. An epoxy coating was placed on the inside surface of the tank because molasses, with a pH around five, can be corrosive to plain concrete. In fact, the acidic nature of molasses may have played a role in the deterioration of the original steel tanks.

The CIP raft slab includes a large ring beam under the walls and pads for the internal columns that support the roof. Foundation pads and buttress sections were precast and connected on site to the rest of the steel prior to casting the ground beams and floor slab.

All wall panels are produced from one semicircular steel mold, with full-height stainless steel form lining to give the tanks a smooth finish. Each wall panel is 18 in. thick and the post-tensioning anchors end in buttress sections, which are 27.5 in. thick.

Walls and buttress sections are erected on site using a vertical CIP connection that is 8 in. wide to join the pieces. The roof is comprised of inverted, prestressed T-beams supported by precast columns, and is decked with 8-in. hollowcore planks. A structural screed is then cast. To achieve the desired adhesion and remove laitance and contaminants, all surfaces are shot-blasted. Finally, an external ladder and handrails are fitted to the structure and an ultrasound measuring gauge, used to monitor the volume of molasses, is extended through the roof. Tanks are hydrostatically tested to full capacity using seawater.

A not-so-sticky situation

Molasses presents an interesting storage challenge, but precast concrete provides an effective, durable solution that is built to last. Thanks to the strength of precast concrete, molasses can follow its proper path from storage to customer, allowing us to consume the products we enjoy while keeping the sticky material out of our streets and waterways.

Sue McCraven, freelance writer and NPCA technical consultant, is a construction engineer and environmental scientist.

Photo Credits:
Pages 6-7 – Preconco Limited
Page 8, Top Left – Boston Public Library, Leslie Jones Collection
Page 8, Center – Preconco Limited
Page 9 – Preconco Limited

(Endnotes)

1 http://www.gisbarbados.gov.bb/plugins/p2_news/9449
2 To view a Preconco video of molasses tank precast panel installation, see http://www.youtube.com/watch?v=Urs5T733_gg
3 https://slice.mit.edu/2012/04/06/great-molasses-flood/
4 http://news.nationalgeographic.com/news/2013/13/130917-molasses-oil-spill-hawaii-honolulu-cleanup/


CHILDREN'S MUSEUM
ALLIANCE

Firmly Planted

Precast concrete provides the perfect solution for a project involving a tight schedule and a tight squeeze at Navy Pier.

By Shari Held

Boasting nearly 9 million visitors annually, Chicago's Navy Pier is one of the Midwest's top attractions. It's home to Pier Park, the Children's Museum, the Pepsi Skyline Stage and a wide variety of shops and restaurants. Soon, thanks to the installation of 59 massive precast concrete tree pits along the South Dock, Navy Pier's only going to get better. The precast concrete work is part of a $115 million-plus renovation designed to give the space a more "green," contemporary look.

"We're going to elevate the pier to become a world-class destination," said Navy Pier Communications Director Nick Shields. "Once our renovation is complete, visitors could potentially increase by 2.5 million."

Phase 1 of the overall project is slated for completion in time for Navy Pier's centennial anniversary celebration in 2016. Areas targeted for renovation during this phase include the public spaces at South Dock, Pier Park and East End.

"This is something that's very important to us," Shields said. "We're already in Phase 1 of our reimagination of the pier, which involves renovating the South Dock, our main walkway."

As visitors stroll along South Dock, their experience will be enhanced by the addition of rows of mature shade trees. Approximately 200 mature trees and other greenery will be planted to make the area more attractive and eco-friendly. The work it took to make this happen will likely be an afterthought for them.

But Leo Schlosberg, principal of Woodstock, Illinois' Cary Concrete Products and Mark Wieser, vice president of Wieser Concrete Products in Maiden Rock, Wisconsin, know what it took.

Hammering out the design details

Schlosberg initially heard about the job from general contractor Madison Evans Construction Group and contacted Wieser based on prior successful collaborations and Wieser Concrete's significant experience with both large and custom projects.

"We've done a lot of work with Cary Concrete over the years," Wieser said. "Leo goes out and finds projects – a lot of times unique ones – and then he'll come to us to produce them."

The original design called for tree pits created in multiple pieces, requiring many difficult field measurements. It also specified a combination of precast and structural steel. The companies also had to contend with a tight window of time between when the trees could be planted and when South Dock needed to open for peak tourist season.

By the time Schlosberg bid on the job, Madison Evans had dropped structural steel in favor of a 100% precast solution.

"Going with all precast was quicker and more cost-effective," Wieser said. "It also involved less on-site labor."

In addition, design specifications were reduced to the basics – the number and overall size of each of the pits, the dimensions and thickness of the precast concrete, and the constraints – making the project more like design-build work. Still, the job was complex. Nothing was standard, leaving Wieser and Schlosberg with the task of how to manufacture the tree pits.

Issues of size and weight were integral to their decision process. There were eight different sizes of tree pits. Producing the largest pit, which was 28 ft long, as one piece would require non-standard shipping. This would also add to the cost of the project. Additionally, Wieser and Schlosberg weren't sure the pier could support the combined weight of an oversized delivery truck, tree pits weighing up to 34 tons and a large crane to position the pits in their permanent home.

"What we did was design the tree pits so they could be produced in two pieces and bolted together on site so we could get them there," Wieser said.

Schlosberg presented their plan to the general contractor and it was accepted. Now, their race against the clock began.

Repositioning the drain

After the contract was awarded, Schlosberg, who has years of experience working in landscape construction, modified the original drainage system details to provide a healthy environment for each of the largest tree pits. The root balls of the mature trees measured more than 7 ft in diameter. In addition to proper drainage, they need plenty of soil and air to thrive. The contract showed a drain in the corner. That location would require up to 3.5 in. of slope, making the floor of the opposite corner about 9.5 in. thick.

"That's wasting concrete and taking up room from the tree," Schlosberg said.

"We wanted to make it so the water would drain with minimal impact on floor thickness and have it be efficient and simple for forming, production and in the field."

Schlosberg's solution was to have the pit drain across the shortest dimension. Both halves drain to a small flat spot in the center of the long, or joint, side. One of the halves gets an 8-in. blockout that allows a drain body to be easily installed in the field. The other half remains flat with no blockout.

Creating the prototype

Wieser's piece of the puzzle was designing the mold and determining how to assemble the joint and the connections.

Wieser Concrete's form fabrication division used a modified box culvert mold and cast it upside down to create each half of the tree pit. The molds have a tongue-and-groove detail. If off just a fraction, they wouldn't fit together properly. As a result, they were manufactured to very tight tolerances.

The main concern was how to seal the two pieces together since one specification was that the tree pits needed to be watertight. Wieser considered several options while working on the drawings but decided on a joint with a keyway. A compressible sealant, standard for manholes and culverts, was used to seal the joint.

"It was the best solution to lock the pieces together and make the pit watertight," Wieser said.

As soon as the first few pieces were completed, Wieser Concrete assembled them in the shop to demonstrate how the two halves would fit together, easing everyone's concerns.

To meet the tight schedule, Wieser employees worked two overtime shifts, producing up to four pieces per day. Between March 18 and April 11, the company delivered 31 tree pits.

Challenging logistics

Getting the pieces delivered was one of the biggest challenges of the project. But that was just part of the issue.

A residential tower located across the street from South Dock required compliance with noise ordinances. No work – including deliveries – could begin until 8 a.m., which meant the delivery trucks had to battle downtown Chicago's rush-hour traffic.

Once the trucks arrived, they had to stick to a limited pathway obstructed by the large holes cut into the pavement to accommodate the tree pits. This left very little space for staging.

"We had to work closely with the general contractor to get this done," Schlosberg said. "From my perspective, they were a very fine, cooperative group and easy to work with. And I think from their perspective both Cary Concrete and Wieser Concrete gave them good service."

Enjoying success

The final challenge was assembling the tree pits on site. The rectangular openings in the pavement of the dock went all the way down to the steel beams that form the structure of the pier. Steel baskets were placed on these beams. Each half of the tree pit needed to be placed into the appropriate basket and then assembled.

There was very little clearance between the outside of the precast and the steel basket. Positioning the first half was the easy part. Positioning the second half to ensure workers could apply the sealant, slide the two pieces together and bolt them with the keyway fitting was where it got tricky. That's where taking the time to assemble the first few pieces in the plant paid off.

"If we'd first learned there was a problem when they tried to install it in the field, it would have been a disaster," Schlosberg said.

Assembly for each tree pit took only about 30 minutes. "They actually got installed more quickly than I expected," Schlosberg added. "It went in very nicely. Wieser Concrete located the lifting points and installed the lifters with precision, so the pieces hung plum. It made a lot of people happy that it went together so nicely."

All that remained was planting the trees, adding a steel plate over the tree pit and grating around the tree trunks. Visitors to Navy Pier can now enjoy the space's new "green spine."

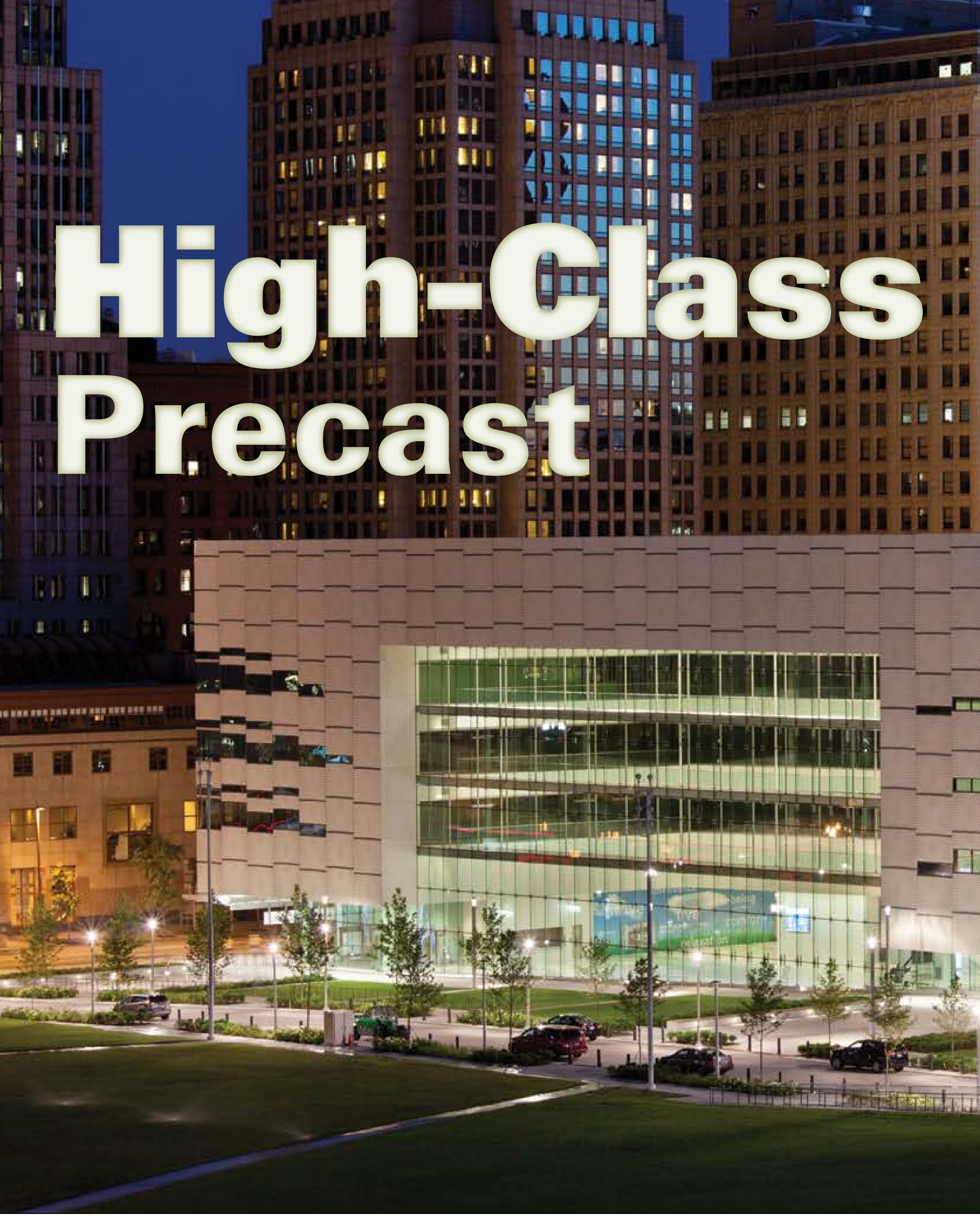
"It's really rare in this business that something goes better than you expect," Schlosberg said. "It was a very aggressive schedule, but we were able to pull it off." PS

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

All photos courtesy of Leo Schlosberg.

The installation of 59 massive precast concrete tree pits helps enhance the visitor experience at Chicago's Navy Pier.

High-Class Precast



Whatever the application, precast concrete products offer the aesthetic appeal engineers and architects seek in designing high-end projects.

By Mason Nichols

As the age-old expression goes, "Beauty is in the eye of the beholder."

For some, precast concrete's beauty lies in its ability to be used for any application imaginable, from roadwork to stormwater systems and beyond.[1] Others find beauty in the material's sheer strength, marveling at precast's durability even in the face of extreme weather.[2] But what about appearance?

Precast concrete is often considered more utilitarian than attractive, but as the following projects illustrate, it is more than capable of achieving the design aesthetic necessary to bring class and style to any construction project.

The center of attention

Early in the 20th century, a group of architects in Cleveland, Ohio, designed the Burnham Mall, a vast public space located in the heart of the city surrounded by signature buildings. More than 100 years later, precast concrete has become part of the mall's storied history.


Implementing a precast concrete solution for property owner Hall Financial Group reduced costs and shortened the construction schedule.

Located on the periphery of the space, the Medical Mart is a four-story exhibit hall for medical devices connected to the city's convention center. The structure, designed by LMN Architects of Seattle, Washington, features precast concrete cladding that ties into the look of the masonry and limestone buildings also situated on the mall. According to Rafael Viñoly-Menendez, LEED AP and principal for LMN, specifying precast allowed the flexibility necessary to achieve important project goals.

"We were looking for a material that would be modern in the sense that it could be constructed fairly rapidly and essentially with a curtain wall system as opposed to traditional load-bearing masonry," he said. "We also wanted to do something that captured some of the detailing in the historic terracotta buildings."

To meet these requirements and further highlight Cleveland as the mecca for medicinal research in the U.S., LMN created an abstracted DNA helix design for the precast concrete panels.

"Both the pattern of the panels at a small scale and then the bigger composition between the precast panels and the glass has the helix design," Viñoly-Menendez said. "So it's a series of light and dark rectangles."

Due to the central location of the project, LMN worked to ensure the completed design offered a refined, high-end appeal. Thanks to precast concrete, Viñoly-Menendez feels the project was a success.

"The Medical Mart is a building in a really prominent location, and the last thing that you want is for it to be perceived as second-class or less than what's around it," he said. "What we liked best about being able to use precast is that it gave us a lot of freedom and flexibility while still offering a look at the right level of finish and quality."

Napa Valley know how

In the wine country of northern California, class isn't just a nice to have – it's a necessity. So when Superior Concrete Products of Euless, Texas, was contracted to manufacture and install a combination sound wall and fence solution at the foothills of Napa Valley, precast concrete was the material of choice.

Due to the property's proximity to both the highway and a local school, property owner Hall Financial Group sought a fence solution that would reduce noise and provide the aesthetic look visitors expect from the region.

Mark Depker, president of Hall Financial Group's management division, had previously seen a precast concrete fence system near his home in Texas. As a result, he phoned Todd Sternfeld, CEO of Superior, to determine whether Sternfeld could provide an optimal fencing solution.

"They wanted to tie in the masonry roots, but of course the cost of doing that would have been very expensive and difficult with a continuous foundation," Sternfeld said. "In our case, ease of installation plays a role because we can just come in there and drill holes."

In addition to reducing costs, using precast also resulted in a much shorter construction schedule. According to Sternfeld, after receiving approval from the state, the fence was installed in one week.

Ultimately, the finished project provides the attractive appeal visitors look for while simultaneously offering the strength and durability necessary for a long and maintenance-free service life.

"In this kind of application – as well as many other applications – people are looking for something that aesthetically sets off the property; something that provides that curb appeal that's going to make them feel warm, comfortable and invited," Sternfeld said. "Yet it still has a durable, robust look to it. When people find out they're looking at a concrete fence, they just freak out."

Multi-million dollar precast

For Travis Hite, lead designer with Weber Design Group of Naples, Florida, crafting a luxurious home is all about adhering to a very specific design aesthetic.

"When people come to us, they're looking for a certain style and a certain flare with the drawings," he said. "This is something which we can handle by using precast features."

While Weber designs a wide variety of house plans, the West Indies style has become a particularly popular option in 2014. One West Indies spec home, completed earlier this year in downtown Naples, prominently features a variety of precast concrete products.

According to Hite, the home includes white precast banding, precast caps and bases, and sills and headers around the windows and doors. "If we're going to use a West Indies variation, we're going to use more of a flat stock," he said. "Using the precast allows us to enhance the look of the clean lines."

Specifying precast is also important in ensuring an extended lifespan for the home. As Hite explained, other products may deteriorate quickly, creating issues for the homeowner.

"A lot of times there are materials like plastic that tend to fade over time or crack, split or peel apart," he said. "The longevity of the home is something that we think about when using precast."

This also resonates with homeowners, who, in addition to seeking style and looks, often associate beauty with permanence.

"For the price range of these houses – they are multi-million dollar homes – you want it to have a substantial feel," Hite said. "You want it to feel sturdy and strong."

Combining class with supreme durability, precast concrete remains up to the challenge.

Not just a pretty face

If beauty is indeed in the eye of the beholder, precast concrete should easily catch the eye of architects and engineers throughout the industry. After all, who wouldn't want to select a building material that's as durable and versatile as it is attractive? Any project, any angle, any design – precast concrete does it all in style. PS

Weber Design Group specifies a wide variety of precast concrete products in their luxurious home designs.

Mason Nichols is NPCA's external communication and marketing manager.

Photo Credits:
Pages 16-17 – Jim Maguire
Pages 18-19 – Nanci Kerby
Pages 20-21 – Tom Harper Photography

(Endnotes)

1. For examples, see precast.org/beatenpath and precast.org/water.
2. Visit precast.org/inanyweather to learn more.

THE MANY FACES OF PRECAST

Exceptional architectural precast concrete designs reflect innovation, history and culture found around the world.

By Sue McCraven

Seen or unseen, precast concrete is everywhere. Underground products such as manholes, utility vaults and pipe serve as the backbone of global infrastructure systems, often out of plain sight. Above ground, precast concrete functions as the centerpiece of some of the most awe-inspiring projects. As the following examples from across the world illustrate, precast concrete is just as aesthetically pleasing as it is functional.

DREAMSCAPE: LOUISIANA STATE MUSEUM & SPORTS HALL OF FAME, NATCHITOCHES

Precaster: Advanced Architectural Stone

Architect: Trahan

Engineer: LBYD

Completed: 2013

The fluid, soothing design found at Louisiana's State Museum and Sports Hall of Fame may place a visitor into a dreamlike state as they walk the winding halls and corridors. The museum, which overlooks the historic Cane River Lake, captures shapes and textures that emulate Natchitoches' local terrain and winding rivers, fusing two seemingly incompatible venues – sports and history – with exceptional design. According to Trahan Architects, the site greatly influenced the interior design. The "fluid shapes" of the corridors, or "river channels," are separated by structures, or "masses of land."

Advanced Architectural Stone created more than 1,150 precast concrete panels that are supported by a custom structural steel frame beneath.

PRECAST PROFILE LOCATION MAP

HITTING HOME: GARNER VETERANS MEMORIAL, NORTH CAROLINA

Precaster: Lucas Concrete Products Inc.

Architecture: Clearscapes

Artist: Thomas Sayre

Completed: 2013

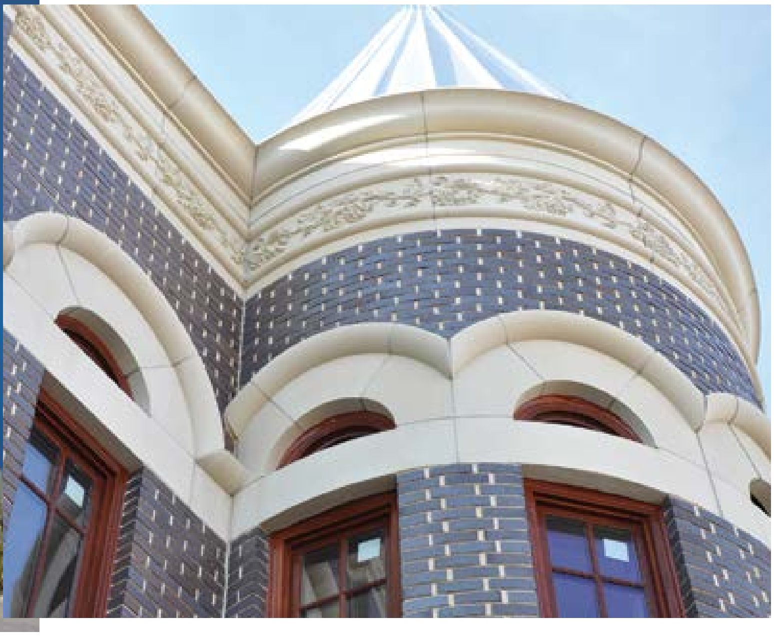
More boys and young men from North Carolina fought and died in the American Civil War than any other state in the Confederacy. The local veterans association in Garner, North Carolina, wanted to honor the ultimate sacrifice of all local soldiers lost in conflicts in a memorial that would give visitors an emotional connection with the fallen warriors. Garner Veterans Memorial's architecture achieves the shared objective.

The Architectural Precast Association awarded the memorial the APA Design & Manufacturing Excellence Award in 2013. "This really wowed us," jury members said.

The following is Clearscapes artist Thomas Sayre's detailed explanation of the design process.

The Garner Veterans Memorial is the result of a competition to create a place of both education and remembrance to honor the veterans of Garner, North Carolina. Individual bands of precast concrete and stone establish walls representing conflict, while benches offer peace, marking 24 decades of our nation's past and the series of conflicts that have brought us to today.

Each of the 37 precast concrete wall panels was individually molded and poured using an "earthcasting" technique. Clay is broken into clods and the soil is packed into molds to create the texture of broken ground, the soil of the plowed field or the exploded surface of warfare. The concrete was then pigmented with iron oxide to match the red clay soil. The surface of the earthcast panels protects the memorial's smooth inner granite panels, where each conflict is described and the names of the fallen from Garner are remembered.



A SLANTED VIEW: BELLA SKY HOTEL, COPENHAGEN, DENMARK

Precaster: Contiga Tinglev
Contractor: NCC
Architect: 3XN
Engineer: Rambøll
Consulting Engineers (M&E): EKJ
Size: 452,000 sq ft, 23 floors
Completed: 2011

Scandinavia's largest hotel, Bella Sky, adds modern elegance to Copenhagen, Denmark's capital city. It was designed as the perfect world-class structure for the trending neighborhood of Ørestad. "We have knowingly worked towards designing a building unlike anything else in Copenhagen – and we did that because Ørestad, which is a new city neighborhood, is also unlike any other place in Copenhagen," said Kim Herforth Nielson, principal and founder of 3XN, the project architects.

3XN designed Bella Sky's two towers to lean apart at 15 degrees, a daring architectural approach. Tilting 65 ft more at the top than at the bottom, the towers are the first tilted precast concrete construction in the world.

"The effect of the leaning towers has also resulted in corner rooms where the building angles create a view which is actually underneath the room," Nielsen said. "It gives the illusion of floating above the view itself."

In addition, one tower bends outward by 12 degrees, making the 250-ft structure appear to twist in the wind. Located near the Copenhagen Airport, the hotel could not be designed vertical due to flight safety regulations. Aluminum and glass façade panels cover the precast concrete building, which includes hollow-core slabs, beams and internal columns.[1]

"Abroad, a building such as Bella Hotel would normally be built using in-situ concrete or steel," said Kaare Dahl, project engineer at Rambøll. "But in Denmark we have a tradition of using precast concrete units. It is cost-effective, results in fewer flaws in the individual units and is far more comfortable to work with."

The Danish Precast Concrete Association is proud of the Bella Sky Hotel. "Bella Sky in not only an icon for precast, it also has moved the limits for precast," said Poul Erik Hjorth, director of DPCA. "When you can design and construct such a building with concrete elements; you can use precast solutions everywhere."

Bella Sky Hotel recently received the 2014 fib Award for Outstanding Concrete Structure from the International Federation for Structural Concrete.

LINKING HISTORY: GRAPEVINE CONVENTION & VISITORS BUREAU, TEXAS

Precaster: Advanced Architectural Stone
Contractor: Byrne Construction Services
Architect: ARCHITEXAS Inc.
Mason Contractor: Clay Hunt / J & E Masonry
Completion: 2012

Grapevine, Texas, a community just northwest of Dallas, grew in prosperity when the railroad linked the city with Dallas. To maintain the rich and deep history of the town as a transportation hub, the convention and visitors bureau has preserved the old railroad hotel façade architecture in its newest building.

According to Advanced Architectural Stone, the specs for the center called for a series of storefronts that would mimic the rustic style of the Old West found in the 1800s. Cast stone copings, pier caps and water tables[2] all were formed using a grapevine motif similar to the original wooden façades.

With its detailing work, AAS's achievement of exceptional architectural intricacy for the building won many accolades, including the 2012 Architectural Precast Association Award of Excellence – Design & Manufacturing & Craftsmanship, and the Construction Specifications Institute Award for Manufacturing & Design Excellence.

CARIBBEAN FLAVOR: PORT FERDINAND LUXURY RESORT, BARBADOS, WEST INDIES

Precaster: Preconco Limited
General Contractor: Jada Builders
Architect: Michael Gomes Architects
Completed: Phase I completed in 2013, Phase II in 2014

Port Ferdinand Marina and Luxury Condominium Resort is an exclusive residential resort set on 16 acres just north of historic Speightstown, Barbados. The resort marina features 120 yacht berths and 83 luxury homes, each with captivating views of the breathtaking Caribbean Sea.

Preconco Limited, an NPCA member located in Lears Quarry, Lears, St. Michael, manufactured and installed all the precast and prestressed concrete components for the resort's all-precast concrete superstructure shell. The "cross wall" construction method uses precision-engineered and factory precast concrete custom components for a more modern and effective building approach.

"We were thrilled with the opportunity to be involved with the development of the Port Ferdinand Luxury Resort & Marina," said Mark Maloney, Preconco CEO. "Given the design and architectural flair of this luxury property, precast was the obvious choice for this project. Precast concrete is an efficient, cost-effective product, which allows for flexibility in design, speedy installations and high quality structures.

"We are proud to have had the opportunity to highlight precast concrete through the construction of this world-class project."

CELLULAR ARCHITECTURE: LA TROBE INSTITUTE FOR MOLECULAR SCIENCE, AUSTRALIA

Precaster: Advanced Precast
Contractor: Watpak Construction
Architect: Lyons
Engineer: Meinhardt
Size: 118,000 sq ft
Completed: 2013

The design for the new La Trobe Institute of Molecular Science in Victoria, Australia, is bursting the bonds of typical campus geometry.

According to architect Carey Lyon, "The campus master plan dates back to 1968 and the objective was clear – the design of this new building is to break the mold belonging to the decades of the 60s and 70s. Obviously, we gave the façade a visual metaphor for cell research."

From the 200-mm thick precast external wall, hexagonal precast concrete cells blast out of the structure's façade to starkly symbolize cell research. And the façade is made all the more dramatic and daring with the use of vibrant colors and wood finishes. Notice that the hexagons are positioned randomly and even offer spaces for students and classes to meet.

41X: AUSTRALIAN INSTITUTE OF ARCHITECTURE VICTORIA CHAPTER

Precaster: Euro Cast

Contractor: Hickory Group

Architect: Lyons

Engineer: Winward Structures

Size: 307,000 sq ft, 22 floors

Completed: 2014

Developed by the Australian Institute of Architects, 41X is a 22-level, Five Star Green Star[3] tower that sits on a small footprint of about 300 sq ft. 41X targets carbon neutrality throughout its 30-year lifespan – accounting for embodied energy, base building operational energy, transport and waste.

Besides the Institute, 41X offers a rooftop terrace and is home to retail operations, including a café and bookstore. A striking sculptural precast concrete exterior forms a stairway design that, according to Adrian Stanic, director of Lyons Architects, "explores the idea of joining together a public and commercial building by connecting the city street space with the Institute's occupied levels."ps

Sue McCraven, freelance writer and NPCA technical consultant, is a construction engineer and environmental scientist.

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Page 26 – John Gollings

(Endnotes)

1 More than 7,000 precast elements were used in the main structural system.

2 In masonry architecture, a water table deflects water from running down the building's face or to the foundation.

3 Developed by Green Building Council Australia, Green Star is a comprehensive rating system assessing the sustainability of buildings constructed in Australia. For more information, visit gbca.org.au/green-star/green-star-overview/.

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Watertightness of Precast Concrete

The relationship between cement and water is crucial in the manufacture of strong, durable precast concrete products.

By Claude Goguen, P.E., LEED AP

If someone asked you to name the greatest duos of all time, you might say Penn and Teller, Simon and Garfunkel or Ben and Jerry. But what about hydrogen and oxygen? Water is the result of the bonding of one oxygen atom to two hydrogen atoms, and none of us would be here without it.

Another duo that has had a significant impact on modern history is cement and water. Combining the two creates a chemical reaction known as hydration, resulting in cementitious paste. Add in aggregates and we get concrete, the second most used material in the world, right after… you guessed it, water.

Although concrete needs water, the two have a bit of a love-hate relationship. Water is a main ingredient, but once concrete has hardened, water can also lead to its destruction. This is a challenge faced since the Romans used concrete to build the Pantheon. So how do we make concrete watertight?

WATERTIGHTNESS, PERMEABILITY AND POROSITY

Watertightness is the ability of concrete to keep water out or in. In other words, the goal is to make concrete virtually impermeable. Precast concrete is used for many purposes – one of the most common is to hold or convey fluids. For structures to fulfill this purpose, they must be watertight.

At the same time, in order for damaging chloride ions, sulfate ions and other aggressive chemicals to make it into concrete, water is required for transport. So while watertightness is important to keep fluids in, it is also important to keep harmful chemicals and ions out.

Concrete is a porous material. Manufacturers employ many methods to control the amount of water and air that remains in hardened concrete, but pores will always be present. Precasters are always trying to minimize porosity, mainly by reducing the water content in the mix. The water to cementitious materials ratio (w/c) is the weight of water divided by the weight of cement. Ideally, precasters want exactly the right amount of water to react with a given amount of cement. However, the mix must be placed in formwork and consolidated around reinforcing. This requires the mix to have a certain measure of workability. The use of water and admixtures enhances the ability for concrete to flow and be placed properly. Any water that is left over after cement is hydrated ends up forming pores in the concrete.

Permeability is the ability of a given concrete to allow liquids or gases to pass through. Permeability is influenced by porosity, but the two are not directionally proportional. We can have a porous material that is also impermeable. Permeability depends not only on the number of pores, but also their size, orientation and connectivity. Despite the presence of tiny pores, however, it would take water approximately 4,800 years to travel through a 6-in. concrete wall if the concrete is of good quality.

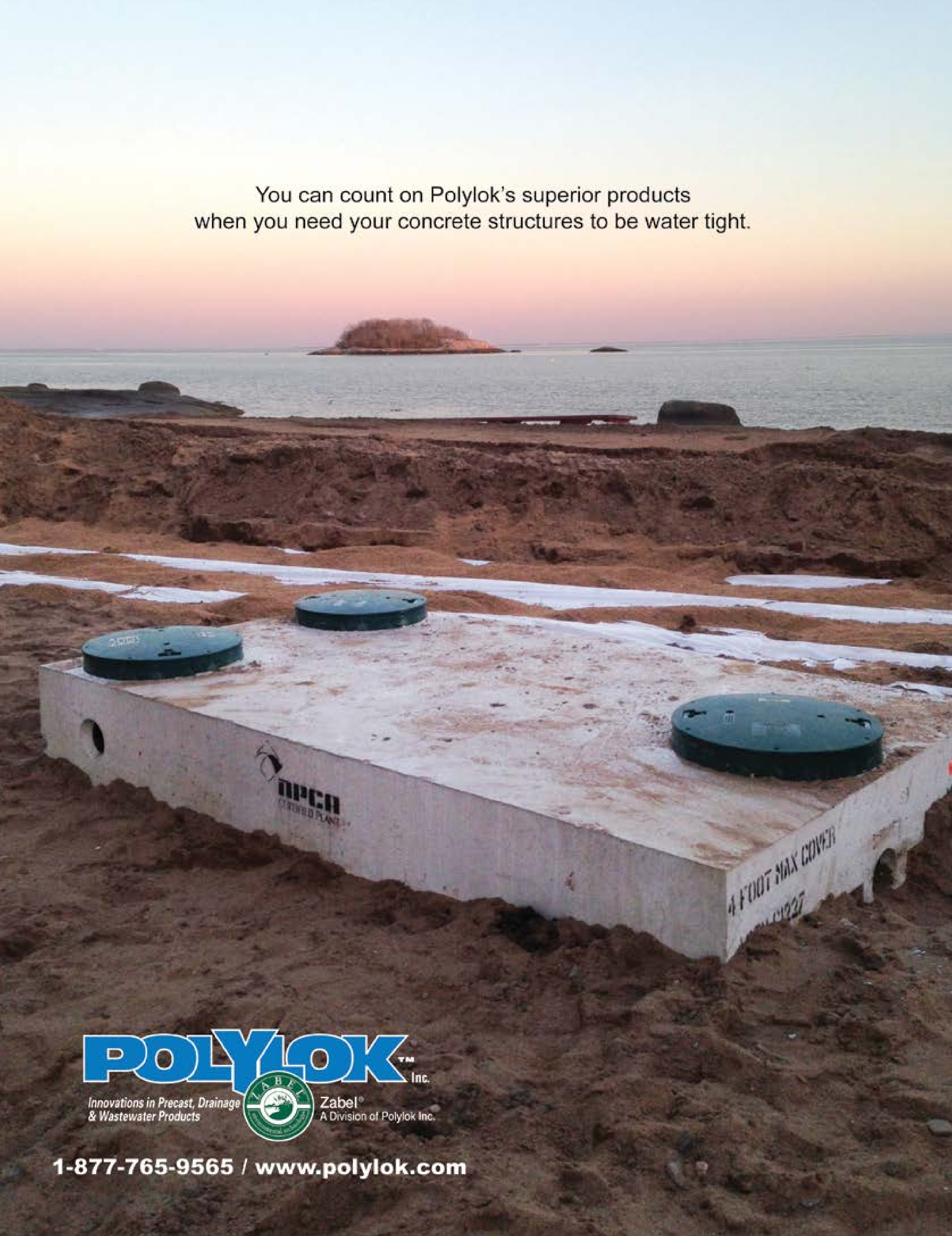
PATHWAYS FOR ENTRY

In terms of the ability for liquids to pass through concrete, there are three roads to take. Liquids can go through the paste (cement and water), the aggregate or the paste to aggregate transition zone, which is commonly referred to as the ITZ (Figure 1). We will look at these three phases separately.

PASTE. Cement and water react, creating a hydrated product. The paste is where pores left from air and water are found. Low w/c ratio is the prime factor in minimizing these pores. Proper curing of concrete products also plays an important role here, as the hydrated product will not fully form unless it is given the time, temperature and moisture it needs.

AGGREGATES. In general, aggregates may have a lower porosity than the surrounding paste. However, depending on the type, aggregates can be more permeable due to the increased size of the pores. The permeability of mature, hardened paste kept continuously moist ranges from 0.1×10^{-12} to 120×10^{-12} cm/s for w/c ratios ranging from 0.3 to 0.7. The permeability of commonly used concrete aggregate varies from about 1.7×10^{-9} to 3.5×10^{-13} cm/s. Selecting an aggregate that has low porosity, low absorption and low permeability is important to aid in the watertightness of the concrete. The aggregates also need to be clean and free of deleterious substances.

ITZ. This zone, surrounding the aggregate particles, is very thin. The shape, size and orientation of the aggregates have an influence on the thickness of the ITZ. The ITZ has a tendency to contain fewer cement particles, and consequently, more water. This can lead to higher porosity in these areas and if the ITZs are linked, can also provide a high permeability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area through the concrete. Proper curing, low w/c ratio and use of supplementary cementitious materials (SCMs), chemical admixtures and additives can strengthen this zone and make it more watertight.

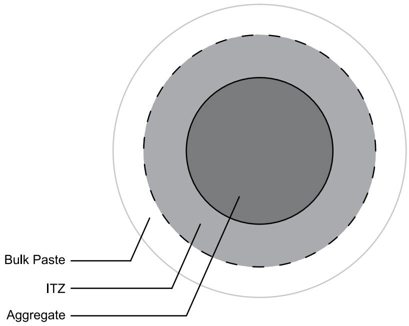

Figure 1 – Three Phases of Concrete Structure

MAKING WATERTIGHT TIGHTER

Precast concrete manufacturers are in the business of making strong, durable products. Durability implies low permeability, so what are manufacturers doing to ensure their precast concrete structures are virtually impermeable?

W/C RATIO. The w/c ratio is the most important factor in making a watertight precast concrete structure. Producers work tenaciously to find the absolute lowest w/c ratio that will enable proper casting. Quality control technicians precisely calculate the moisture content of the aggregates and factor in water from admixtures to make the necessary modifications to maintain the optimum w/c ratio.

Concrete's strength has a direct relationship with the w/c ratio. By specifying high-strength concrete, the w/c ratio will be low, and, as a result, there will be reduced porosity and permeability. Low w/c ratios produce a strong concrete that can far exceed specified 28-day strengths, and very low porosity that will make it impenetrable to harmful elements.

AGGREGATES. Producers are judicious in their selection of aggregates to ensure they are as impermeable as possible. For that reason, most issues with permeability will occur in the paste. Still, quality control managers will select an aggregate gradation that will maximize aggregate volume while ensuring that enough paste is present to fully envelop the aggregates. The aggregates are also closely inspected and tested to ensure they do not contain any deleterious substances or excess dirt.

SCMS. Producers use SCMs for their many benefits, including permeability reduction. According to PCA's Design and Control of Concrete Mixtures, "These materials may or may not reduce the total porosity to any great extent, but instead, act to refine and subdivide the capillary pores so that they become less continuous." SCMs also have a binding effect that can inhibit ingress of chloride ions into the concrete. Silica fume and metakaolin are particularly effective in reducing concrete's permeability.

ADMIXTURES. Producers use many different admixtures to modify fresh or hardened concrete properties.

Air-entraining admixtures can be beneficial to reduce permeability due to their ability to enhance workability and cohesiveness, therefore reducing water demand.

Water-reducing admixtures maintain or even increase workability while lowering mix water content. The advent of water reducers and the ongoing technological advances in the development of these products have led to overall reductions in w/c ratios and more watertight precast concrete structures.

An example of a coating applied to an underground structure installed in downtown Indianapolis.

Admixtures such as accelerators and retarders are used to control concrete's rate of set, especially during extreme weather conditions. This set control fosters proper hydration and results in decreased permeability.

Permeability-reducing admixtures are gaining popularity in concrete manufacturing. They can be divided into two categories: non-hydrostatic (PRAN) and hydrostatic (PRAH).

Due to their hydrophobic nature, PRANs act as a water repellent and are traditionally used to reduce the absorptive tendency of concrete. This is commonly referred to as damp proofing. These products are generally used where there is little or no hydrostatic head.

PRAHs, on the other hand, are hydrophilic, meaning they react with water. Crystalline waterproofing additives exemplify this technology. The active ingredient in these products reacts with byproducts of cement hydration to form additional CSH gel and/or precipitates that block microcracks and capillaries. This blockage will resist water ingress under hydrostatic pressure.

CONSOLIDATION. Consolidation serves many purposes. One of the most important is to ensure that air does not remain trapped in the concrete after it has been placed. Improper consolidation can lead to honeycombing and aggregate segregation, making it much easier for water to enter the concrete.

CURING. The curing period of a precast concrete structure is critical in determining how durable it will be. Proper curing requires three things: time, temperature and moisture. Producers start with a low w/c ratio and then must work to keep that moisture in the concrete to enhance proper hydration.

SEALERS, PENETRANTS AND COATINGS. Properly designed, mixed, placed and cured precast concrete can stand up to most conditions and serve as a long-lasting product. However, conditions do exist when additional products may be needed. These are products applied to the surface of hardened precast concrete to reduce the penetration of water and harmful ions into the concrete.

Generally classified as film-forming, sealers block penetration of water by forming a clear protective barrier on the concrete surface. Some are water- or solvent-based while others are epoxy or urethane sealers.

Penetrants, sometimes called penetrating sealers, actually soak into the concrete and enter the voids and capillaries at the surface to form a water-repellent layer. Water will actually bead on these treated surfaces.

Coatings are engineered products designed to form a protective barrier, shielding the concrete from chemical attack. Coatings are typically epoxy, urethane or acrylic, but also include asphalt coatings, polyureas, polyaspartic, and poly and vinyl esters.

TEST METHOD	TITLE	COMMENTS
CRD 163	Test Method for Water Permeability of Concrete Using Triaxial Cell	Best for evaluating concretes with a w/c between 0.4 and 0.7.
ASTM C1556	Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion	Considered a useful method for prequalification of concrete mixtures, but it takes about three months to complete.
AASHTO TP 64	Predicting Chloride Penetration of Hydraulic Cement Concrete by the Rapid Migration Procedure	Less variable than ASTM C1202. Results are not influenced by corrosion inhibiting admixtures.
ASTM C1202 (AASHTO T277)	Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration	Widely used in specifications for reinforced concrete exposed to chlorides.
ASTM C1585	Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes	Initial ingress of aggressive ions by absorption into unsaturated concrete is much faster than by diffusion or permeability.
ASTM C642	Standard Test Method for Density, Absorption and Voids in Hardened Concrete	Not a permeability test, but used as an indicator of concrete quality.

Table 1 – Test Methods for Concrete Permeability

HOW TO TEST FOR PERMEABILITY

Many tests exist to determine the permeability of concrete. One such test measures the electrical conductivity of the precast concrete structure to get an indication of permeability. ASTM C1202, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration," is also called the Coulomb or rapid chloride permeability test. Other tests are indicated in Table 1.

DYNAMIC DUOS

Lewis and Clark, peanut butter and jelly, cement and water… all are influential duos. Unless specifically called for by design, though, water getting into concrete serves no good purpose. Thankfully, precast concrete producers are diligent in finding the best materials and production methods to deliver a product that will keep harmful elements at bay and provide an exceptionally long service life.

Claude Goguen, P.E., LEED AP, is NPCA's director of Sustainability and Technical Education.

References

PCA Design and Control of Concrete Mixtures – 15th Edition

ACI 212.3R-10 – Report on Chemical Admixtures for Concrete

ACI 318 – 11 – Building Code Requirements for Structural Concrete

ACI 515.1 defines waterproofing as a treatment of a surface or structure to resist the passage of water under hydrostatic pressure, whereas damp proofing is defined as a treatment of a surface or structure to resist the passage of water in the absence of hydrostatic pressure.

Photo courtesy of Gate Precast

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