PARKING ISSUE

WINTER 2015

ASCENT

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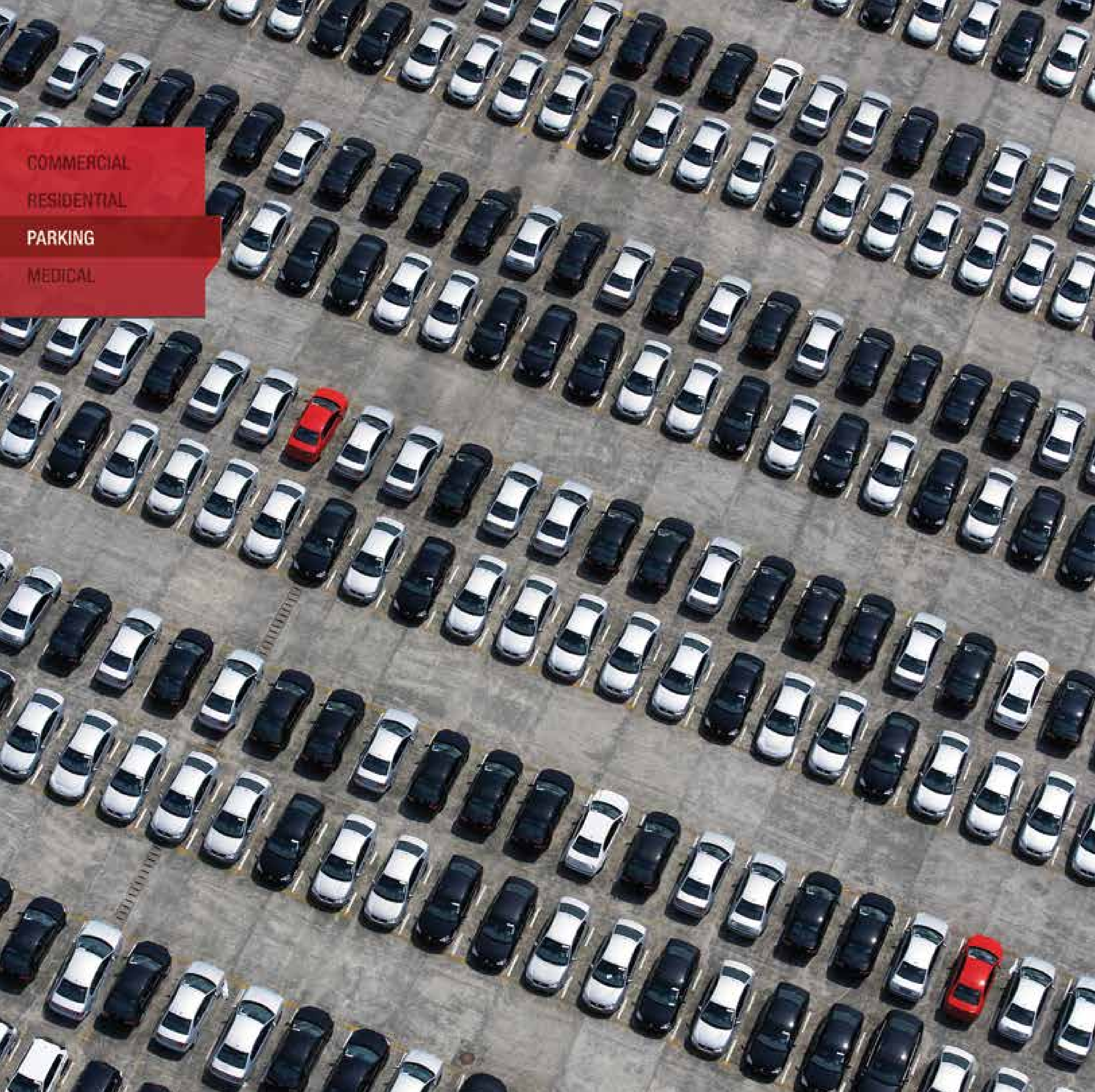

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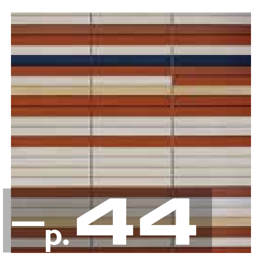

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Precast Concrete Provides High-Performance Parking Structures

Happy New Year! Hopefully, this year will be prosperous for you and the construction industry. Projections for construction are again up this year, by about 9%. Select market segments will do slightly better, such as parking which is projected to rise about 10%.

This growing demand for parking isn't a surprise. Americans have a love affair with cars. Many Americans have a special attachment to their automobiles. It's a symbol of freedom and pride. I can still remember my excitement as a young boy when my father would take us for a ride in his 1963 split-window Corvette Stingray. What a car!

Automobile sales were up in 2014 by 5.8% with more than 16.4 million light-vehicles sold. And with gas prices falling to their lowest point in more than six years, people will be driving more. Of course, this means we will need more places to park, and therefore more parking structures, about 155 million square feet more in 2015.

Today we hear a lot about building high-performance structures, but what is a high-performance parking structures? The definition of a high-performance structure is one that integrates and optimizes all of the relevant attributes based on life-cycle costs. So what are the relevant attributes of a parking structure?

It depends on the specific project and its program. Typically these include creating efficient designs and layouts that maximize parking operations, providing a safe environment for users, and building durable structures to prolong service life, while reducing life-cycle costs. In most cases, accelerated construction is also an important requirement to facilitate revenue generation or meet a facility's opening.

Today, additional aspects such as more detailed aesthetics and architecture, technology, and integration with other operations such as retail may also be very important. The idea is to identify all of these attributes and seek to optimize them.

Precast concrete inherently provides many of the relevant attributes to achieve these goals, such as design and aesthetic versatility, construction efficiency, and resiliency, along with a high-degree of quality and durability. Not only is precast concrete the most commonly used material in parking structures, but it is a natural fit to build high-performance parking structures.

This issue of *Ascent* focuses on innovations and recommended practice for parking structure design and maintenance, addressing many of the issue discussed above. We encourage you to Discover High-Performance Precast.

ASCENT

On the cover: Martha Jefferson Hospital Parking Structure (see page 28). Photo: Kahler Slater, Inc.

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- If you have a project to be considered, send information to Brian Miller, Executive Editor of Ascent.
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Wells Concrete Acquires Hanson Structural Precast

ALBANY, MINNESOTA

Wells Concrete announced that effective November 1, 2014, the company has acquired the Maple Grove, Minn., office and production facilities of Hanson Structural Precast. The combined organization strengthens the company's presence in the Minneapolis-St. Paul area and will enable it to provide a more complete and competitive product offering.

"Hanson Structural Precast fulfills new product and schedule flexibility opportunities for Wells Concrete," says Dan Juntunen, president and CEO of Wells Concrete. "Hanson brings a team of highly experienced professionals, a resume including major stadiums and high-rise office and housing projects, and an outstanding safety record that will contribute to making Wells Concrete a stronger and more competitive organization in the marketplace."

Wells Concrete will be relocating its Golden Valley, Minn., sales, engineering, and construction services office to the Maple Grove Hanson Structural Precast location to streamline business processes. The combined office will operate under the Wells Concrete name. At this time, there are no plans to eliminate any positions.

Terms of the acquisition were not disclosed.

Meadow Burke acquires Thermomass

BOONE, IOWA

Meadow Burke has acquired Thermomass. Thermomass manufactures a range of patent-protected insulation systems for use in precast, tilt-up, and cast-in-place concrete applications. These systems are used in the construction of energy-efficient buildings throughout North America, Europe, the Middle East, and Asia. Thermomass will continue to be operated by its current management team and led by President Tom Stecker.

Clark Pacific to work on two new San Diego projects

WEST SACRAMENTO, CALIFORNIA

Clark Pacific, one of the nation's leading suppliers of architectural and structural precast concrete solutions, has been awarded two signature construction projects in San Diego, Calif. Clark Pacific will furnish precast concrete architectural cladding with glazed panels for the new county courthouse and precast concrete architectural cladding and stairs for San Diego International Airport's new parking and rent-a-car facility.

The \$300-million courthouse project, delivered as a design-build project by Rudolph & Sletten and Skidmore, Owings & Merrill, will be a 704,000 ft^2 (65,400 m^2) courthouse designed to replace the current 48-year-old building. The project will consolidate the separate county courts, criminal trial, family, and civic, into one 22-story building. The estimated completion date is early 2017.

Clark Pacific's contract is to provide limestone-faced, prefabricated architectural precast concrete elements for the project, including walls, glazed window panels, and fully wrapped column covers. The new project will occupy a full city block and will include the transformation of a brownfield lot into a new public park. All precast concrete components will be manufactured in Clark Pacific's Fontana, Calif., facility.

The second San Diego project, a \$316 million parking and rental car facility for the city's airport, will be delivered by a joint venture of Austin/Sundt with design by Damattei Wong Architecture and Simon Wong Engineering. The structure will total 2 million ft^2 (190,000 m^2) and will contain 5000 parking stalls. Clark Pacific's contract includes the manufacturing and installation of precast concrete architectural cladding, and stairways for the structure.

The structure will serve as a central location for rental car customers, with one consolidated airport shuttle serving the new facility, as opposed to the many brand-specific shuttles that have served the airport. The structure will dramatically reduce rental car traffic on Harbor Drive and will relieve congestion around the airport itself.

TLC Names New CEO

ORLANDO, FLORIDA

TLC Engineering for Architecture Inc.'s Board of Directors announces that Michael P. Sheerin, PE, LEED AP BD+C, has been named to succeed Debra Lupton, AIA, LEED AP BD+C, as CEO of the firm. Sheerin, currently serving as the firm's director of Healthcare Engineering, was selected by the board following an extensive search of internal and external candidates. Sheerin will assume the role in early 2015 with an orderly transition until Lupton's retirement on May 1, 2015.

In addition to overseeing TLC's Healthcare practice firm-wide and his involvement on national healthcare standards such as ASHRAE Standard 170 Healthcare Ventilation, Sheerin has held key roles in the design of many award-winning projects, including the Ft. Benning Martin Army Community Hospital, Nemours Children's Hospital in Lake Nona, numerous Florida Hospital projects, and more. He chairs the ASHRAE SPC 189.3P Design, Construction & Operations of Sustainable, High Performance Healthcare Facilities, is vice-chair of ASHRAE 170 Ventilation of Health Care Facilities, chairs the NFPA 99 Revision Committee, Mechanical Sub-Committee, and is a member of USGBC and the Florida Healthcare Engineering Association.

Martin Army Community Hospital

FORT BENNING, GEORGIA

The Martin Army Community Hospital Project is a 745,000 ft^2 replacement hospital for the U.S. Army at Fort Benning, Ga., on a greenfield site of approximately 50 acres. There are three main building masses, an eight-story hospital with six stories above grade and two below grade. Both below grade floors have daylight on the north elevation. There are two clinic wings, separated from each other by a courtyard, and separated from the hospital wing by a Grand Concourse. The Grand Concourse is the main circulating and gathering space, with dining on the lower level, and views to nature out the north, three-story curtainwall exterior.

The exterior skin is primarily 9″ thick insulated architectural precast panels, in two textures with reveals, and glass curtainwall. The precast sandwich panel consists of 3″ of exterior concrete, 3″ of insulation and 3″ of interior concrete, all tied together with carbon fiber shear grid. This high-performance sandwich panel achieves c.i. (continuous insulation) per ASHRAE 90.1, assisting the design team in exceeding the requirements for LEED Silver. The precast concrete was provided by Metromont Corporation.

There are two separate total precast parking decks, one for staff and one for visitors and patients. Each deck is designed for 1,000 spaces, for a total 2,000 car capacity on site. The exterior of each deck has architectural finishes on the integral structural pieces to match the architectural precast panels on the buildings.

The new Martin Army Community Hospital features precast concrete in the exterior skin and the sandwich panels of the main structure. There are also two total precast parking decks built as a part of this project.

EnCon United Announces Corporate Management Team Growth

DENVER, COLORADO

Jack Tubbs has joined EnCon Companies as director of Preconstruction, bringing over 27 years of engineering and construction experience to the EnCon team. In his role, Tubbs' responsibilities include developing and managing new business development opportunities for EnCon Construction, EnCon Renew, EnCon Utah, and Stresscon Corporation. Additionally, Tubbs is responsible for business process initiatives and improvement, preconception design assistance and value engineering, sales, new market development, and product development.

Submit your headline news for consideration in a future issue of *Ascent* to Stephanie Corrigan at scorrigan@pci.org.

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A New Standard for Parking Facilities—Maximizing the Value of Precast for Increased Sustainability in Design and Construction

— Rachel Yoka, LEED AP BD+C, CNU-A

Parking Matters to Sustainability

Parking is often the critical link to our mobility–the connection between where we are and where we want to go. As an industry, parking may not be top of mind as far as sustainability goes, but it should be. Parking and transportation professionals know exactly how important their operations are, linking land use and transportation and crossing the lines between buildings and our roads, bridges, and transit systems.

The International Parking Institute[1] (IPI) is the leading association of parking professionals and the parking industry; members are parking and transportation professionals in the municipal, university, airport, healthcare, and corporate sectors and the business partners that serve them.

IPI recognizes the critical importance of the precast concrete industry to the design and construction of parking facilities. As a result, IPI has partnered with PCI to create advanced educational, networking, and strategic business opportunities tailored to the needs of each organization's membership. These opportunities include collaborative webinars, educational opportunities at annual conferences, and a precast pavilion designed just for PCI members at IPI's upcoming annual Conference and Expo in Las Vegas, Nev., June 29 to July 2, 2015. To learn more about the precast pavilion, contact Brain Miller at bmiller@pci.org.

IPI Creates Sustainability Framework

IPI conducted a landmark survey of its membership to form the basis of a formal sustainability framework in 2011, asking for feedback from parking professionals across all sectors to identify the most relevant and impactful sustainability strategies as an industry. The survey targeted critical strategies that would form a set of guidelines and identified two essential concepts: green building and high-performing building standards for parking structures, and parking facility operations supporting alternative transportation modes.

– Rachel Yoka is vice president of Program Development for the International Parking Institute. Rachel has authored and edited several publications including the first of its kind publication on sustainability and parking design titled "Sustainable Parking Design and Management: A Practitioner's Handbook." She served as the certification chair and board member of the Green Parking Council and led the development of the first industry-specific rating system for sustainability in parking structures.

IPI's *Framework on Sustainability for Parking Design, Management, and Operations*[2], outlines industry-wide goals and action items that provide education, incentives, and forums for sustainable parking solutions. This document identifies primary strategies that include:

- Make informed decisions based on long-term environmental effects related to material and technology selection.
- Use effective natural resource management and reduce waste.
- Increase education and information sharing and promote the use of rating systems and benchmarking tools such as the *Certified Green Garage Standard* for new and existing parking assets.
- Encourage alternative energy sources and energy savings technology, reduce reliance on fossil fuels, and accommodate alternative fuel vehicles.
- Gather data, conduct research, and document case studies to create a body of knowledge about sustainability in parking.

Sustainable Parking Design & Management: A Practitioner's Handbook[3] addresses the complex relationship of sustainability, parking, and transportation. Written by more than 30 experts and peer-reviewed by thought leaders and practitioners in the parking industry, this reference includes chapters on materials, technologies, lighting, and rating systems, including the new Green Garage Standard.

A New Standard Designed for Parking

The Green Parking Council (GPC)[4], an affiliate of IPI, is an organization that seeks to change the nature of parking. Driven by a vision of parking as part of a solution, the GPC provides leadership and oversight for the conversion of parking facilities to more sustainable, environmentally responsible assets.

> *"Green Garage Certification will be transformational for our industry. With so many state-of-the-art parking facilities well on the way to certification, we know that these structures will reap rewards from energy and operational efficiencies. New structures can apply the standard to planning, design, and construction–creating better buildings that minimize environmental impacts and maximize mobility across the industry."*
>
> *Liliana L. Rambo, CAPP, director of Parking Services, Houston Airport System and chair, International Parking Institute, Alexandria, Va.*

Parking professionals acknowledged the importance of the U.S. Green Building Council's LEED ratings system to the sustainability movement. The system has been applied to parking structures in certain circumstances[5]. LEED does not, however, capture the unique attributes of the parking structure building type, in particular with regard to linkages between transportation, parking, and mobility. To fill the gap, GPC developed the *Certified Green Garage Standard*—a new certification and rating system designed specifically for parking structures by parking and transportation professionals who understand the opportunities and challenges these facilities pose.

The *Green Garage Certification Program Guide*[6] defines an eligible garage as:

> A structure designed for the primary purpose of storing vehicles, including multistory stand-alone garages as well as mixed-use structures with a minimum of one supported level above or below grade. Both existing buildings and new construction are eligible for certification. All facilities that participated in the Green Garage Certification BETA or the GPC Demonstrator Site Program are eligible for certification.

The system applies to both proposed/new construction projects as well as existing buildings, including renovation and retrofit for existing facilities. Owners and operators across all sectors have reaped the rewards of energy efficiency measures, saving on energy costs and reducing emissions and pollution from that energy use.

Subject matter experts for each measure reviewed the standard. The Green Garage Certification BETA version (or pilot) of the standard was lauded by reviewers from all relevant disciplines: architecture, engineering, property management, sustainability, energy-efficiency, academia, technology, and urban land management, among others. This process ensured that the program would be applicable and achievable, as well as stringent and meaningful.

This process was enhanced by the BETA program, which had two primary and complementary goals:

- To review and refine the standard by benchmarking it against more than 40 of the most progressive structured parking facilities in the United States and Canada.
- To test the standard against existing garages of varying ages and examine each measure in detail, reviewing objectives, benchmarks, and strategies.

The information and review feedback during this process guided the refinement of the standard prior to its release in June 2014. GPC and IPI are currently partnering with the Green Building Certification Institute (GBCI), the certification arm of the U. S. Green Building Council (USGBC), to promote and implement the Standard. This partnership will enhance not only Green Garage Certification, but sustainability throughout the real estate, parking, and transportation industries.

Essentials of the Standard

Garages can pursue a maximum of 248 points in the 48 program measures. To encourage a balanced approach to sustainability, facilities must achieve a minimum threshold of 20 points in each of the three main categories, described below. Green Garage Certification recognizes garages at Bronze, Silver, and Gold certification levels. Bronze level is awarded at 110 or more certification points; Silver between 135 and 159 points; and Gold at 160 or more.

The measures are organized in three major categories that provide a range of choices with multiple compliance paths, as well as a fourth category for innovation:

- Category A: The Management category focuses on operational decisions that maximize the use of a parking asset while limiting waste. Key considerations in this category include leadership, staff education, and physical and infrastructure needs. Measures of particular relevance include proactive operational maintenance, cleaning procedures, construction waste management, regional and recycled materials, and life-cycle assessment.
- Category B: The Programs category supports new revenue sources, increases customer service, and provides greater marketability. These measures address ingress/egress, alternative mobility solutions, and opportunities for community involvement. Key considerations include garage functionality, Transportation Demand Management (TDM), transportation choices, vehicle choices, patrons, and factors that affect all who interact with the facility.
- Category C: The Technology and Structure Design category addresses the physical attributes that increase energy efficiency, decrease waste, and support mobility. Key considerations include energy sources, energy efficiency, water use and reuse, and technology and materials choices. Measures of particular relevance include coatings, paints, and sealants; ventilation systems; roofing systems; and design for durability.
- Category D: The Innovation category is a provision to address strategies not yet included within the program. This category awards additional points for strategies not specifically included, extraordinary successes in existing measures, and creativity in new technologies, materials, and programs.

The certification program is contained in two primary documents. The *Green Garage Certification Program Guide* contains application procedures, program requirements, and a breakdown of criteria by certification level. Available as a free download, it is frequently updated and provides an introduction to those who seek basic information about certification.

The *Green Garage Certification Standard* is a technical reference document that outlines performance measures and documentation requirements. It draws heavily on the relative experience of LEED, Green Globes, and other ratings systems and applies some of the same relevant and accepted standards. Each measure contains objectives, point values, compliance paths, best practices, and short case studies. At this time, it does not contain prerequisites or mandatory measures. These documents are supplemented by in-person training sessions for Green Garage Assessors and workshops offered to train parking and transportation professionals, as well as design and construction professionals.

Relevant Measures for the Precast and Parking Industries

Each of the measures was included in the standard due to its specific relevance to the asset type. Highlighted here are a few selected strategies to illustrate how the standard approaches the certification process and particularly how precast concrete can contribute to certification.

Six Ways to Get up to Speed Fast on Green Garage Certification:

1. Get a free subscription to *The Parking Professional* magazine. Send an email to membership@parking.org and request a six-month subscription as a PCI member.
2. Download the free Green Garage Certification Program Guide at www.greenparkingcouncil.com/freeCERT.
3. Find a trained Green Garage Assessor to certify facilities. Or become one yourself! Details at www.greenparkingcouncil.com/gga.
4. Invest a few dollars in a copy of the standard–you will need this essential reference to certification. www.greenparkingcouncil.org/certified-green-garages/green-garage-certification-standard/
5. Sign up for the IPI Insider and GPC newsletter at www.parking.org/publications/ipinsider-e-newsletter/subscribe-to-the-ipinsider.aspx and www.greenparkingcouncil.com/news.
6. Attend IPI in Las Vegas, Nev., and participate in the PCI member-only Precast Concrete Pavilion. Contact Bonnie Watts at watts@parking.org.

Measure A1: Parking Pricing. Listed first in the standard, the "parking structure charges for the use of parking spaces, allowing for economic and market conditions to impact patrons' decisions on mode of travel." This measure has significant transportation effects; any pricing affects travel choices. There are many best practices to maximize both the environmental and economic effects of this measure.

Measure A11: Regional Materials for New Construction, Rehabilitation, or Retrofit. This measure is intended to encourage the use of regional materials, which limit the transportation effects of obtaining materials from farther distances that generate increased carbon emissions, fuel use, and pollution. Additionally, this practice supports the local/regional economy. Materials that are manufactured within 300 miles of the project site can earn the facility three or six points. Precast concrete typically makes up a considerable portion of the materials used in garage construction, allowing for many facilities to earn these points through the use of precast concrete alone.

Measure A14: Third-Party Sustainability Certification. Facilities that have achieved a third-party sustainability certification, including LEED and Green Globes, will receive high points under this measure. Structures that achieve greater ratings are awarded the highest point values on a weighted scale. To ensure widespread applicability, it allows for two points under Energy Star Portfolio Manager and the Urban Land Institute (ULI) Greenprint Performance programs. Under each of these programs, using precast concrete in garage construction can add point value toward third-party certification. For example, under LEED for New Construction, points earned for roofing systems contribute to certification, which can then be applied under the roofing systems measure described below.

Measure C5: Electric Vehicle (EV) Charging Stations. This measure is intended to facilitate EV infrastructure to advance adoption of EVs. This measure allows multiple choices to accommodate Level I, Level II, and DC Fast Charging. Point values range and increase as charging times decrease. Facilities that provide EV charging to customers for free garner an extra point. Best practices include integrating charging stations with on-site renewable energy generation or renewable energy purchase programs to link EVs to clean energy.

Measure C15: Roofing Systems: This measure aims to incentivize roofing systems that provide greater environmental benefit. Options include green roof systems, blue roof systems, cool roofing materials, photovoltaic arrays, and high Solar Reflectance Index (SRI) value materials. For most parking operations, the roof of the structure is used for parking cars, making high SRI values the simplest and most cost-effective compliance path. Precast concrete can add considerable value here, merely by specifying a high SRI value concrete mix at the roof level, to combat urban heat island effect.

These measures demonstrate how the standard approaches sustainability and adapts to the unique opportunities in parking garage design and construction, including the benefits afforded by precast concrete toward certification.

Advancing Sustainability

The garages in the planning phases now extend far beyond standard industry practice today. The *Green Garage Certification Standard* is designed to innovate, advance these benchmarks, and provide guidance in the design and construction of new facilities. Precast concrete plays a pivotal role in the certification process. To learn more about the standard, and download the handbook, please visit www.greenparkingcouncil.org.

> *"Nationally, over half of parking structures are constructed of structural precast concrete. Precast concrete is recognized by and can contribute points under Green Garage Certification. Green Garage Certification recognizes and promotes smart use of precast concrete elements, and parking facilities can earn Certification points for employing sustainable precast practices. Anyone planning a new garage or expansion should pay close attention to the Green Garage Standard."*
>
> *Paul Wessel, executive director, Green Parking Council*

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For more information on these or other projects, visit www.pci.org/ascent.

Making the Most, of a Second Chance

Timothy Haahs has designed parking and mixed-use structures to revitalize neighborhoods after he was given his own second chance

— Craig A. Shutt

Timothy Haahs, PE, AIA

Timothy Haahs, PE, AIA, started his design firm in 1994 with the goal of using parking and mixed-use designs to create more active, sustainable, and walkable "people places." His company encourages sustainable design and employee growth, revitalizing everything from the planet to the individual. Haahs established these goals after a life-changing event. He passed out behind the wheel of his car at a speed of 75 mph, a near-tragedy that revealed he suffered from a life-threatening illness.

Haahs had established a successful career in the parking-design industry, becoming a principal at Walker Parking Consultants over the course of the previous 10 years. Following his car accident, he discovered he had cardiomyopathy, a virus that had permanently damaged his heart muscles. Two years of trying multiple procedures, including pacemakers, defibrillators, and various medications, failed to improve his condition. He ultimately was admitted to the hospital and spent six months there awaiting a heart transplant. The chances of finding an appropriate donor and successfully transplanting the heart left his long-term survival potential at about 25%.

The Annapolis Towne Centre Garage provides dedicated spaces that help support the wide variety of uses for the facility, including banking, retail, condominiums, apartments, luxury hotel, fitness center, office space, and restaurants. Photo: TimHaahs.

"I spent a lot of time thinking, reading the Bible, and reviewing my life," he says. "When I finally did receive my transplant, I was given a second chance. I decided to start a new company of my own and try to give a second chance to others."

His interest in parking structures developed during his years at the University of Pennsylvania, where he obtained his Bachelor's and Master's degrees in engineering. After several years working in the nuclear power-plant industry, he was intrigued by the opportunity to work at a parking-design firm.

"In college, we'd studied transportation, environmental issues, and structural design at the same time to encourage us to consider all aspects of engineering," he explains. "I was interested in how I could integrate them. I saw parking structures as the perfect combination of all three."

His illness also proved to be one of the catalysts for the founding of Timothy Haahs & Associates, Inc. in Blue Bell, Pa. The firm's mission statement ("We exist to help those in need") manifests itself through its support of a variety of medical, religious, and charitable organizations. He also co-founded Calvary Vision Church in 1996. In 1998, he was installed as one of the pastors, and the church currently has more than 200 parishioners. (For more on the company's employee programs, see the sidebar.)

Parking's Key Role

When Haahs entered the parking field, the industry showed great potential for improvement, since it tended to be considered more of an afterthought, he notes. "At the time, it was assumed parking had to be an ugly, functional aspect of a project, added after the rest of the building program was designed. But it doesn't have to be isolated and treated that way. It should be considered part of the living space, which will lead to making it more attractive and integrated."

'Parking is never the ultimate destination for those using it, but it's the first and last impression they have.'

Parking plays a key role in attracting visitors and setting the tone, he says. "Parking is never the ultimate destination for those using it, but it's the first and last impression they have. I wanted to capitalize on that interaction and integrate parking with other functions. It was important to convince owners of that significance and to ensure parking designers are invited to work with planners from the beginning."

An example of the role parking plays can be seen at the Philadelphia Zoo Centennial District Intermodal Facility, a four-story, 683-space parking structure built at America's first zoo. The $24-million project at the landmark facility, which attracts 1.2 million visitors per year, improved traffic flow and created a plaza near the main stair tower. The total-precast concrete structure features a "teardrop" shaped concrete seating wall and curved concrete seating to create a community space. The zoo partnered with the city's Mural Arts Program to create colorful, animal-themed murals on the structure's side.

The facility incorporates a pedestrian ramp along its exterior that offers families a convenient and more interesting experience to reach the ground floor. The structure was designed to incorporate retail spaces to further enhance ground-level activity, but the recession curtailed those plans. "It's still possible to include it if they want that in the future," says Haahs.

Large murals decorate the façade of the new precast concrete parking structure at the Philadelphia Zoo Centennial District Intermodal Facility. The project added parking while improving traffic flow and creating a community-centric plaza. Photo: Steve Wolfe Photography.

Great Aesthetic Versatility

Although parking designs in the past maintained a traditional look, those limitations have been relaxed in recent years, he notes. "Parking offers great versatility, because their designs are totally open." Housing, he argues, is limited, because it has to resemble housing and be economical. "As a result, most housing designs look the same. So do offices. Whereas parking can have a traditional look to blend in, or it can be wild, to stand out. We're seeing more contemporary designs. It's a very exciting time."

Urban facilities create particular design challenges. "Parking structures in urban areas need to be more creative. It's important to make those designs attractive and integrate them with the other uses." But hiding the function doesn't always provide the most effective approach. "In many cases, you need parking to look like parking to ensure users recognize it for its function and can be directed to its entrance."

An example is the Annapolis Towne Centre Garage, where developers of the mixed-use facility wanted an attractive "downtown" look that minimized the facility's mass. A wide palette of precast concrete colors and sandblast finishes were used in conjunction with ornamental metal accents, providing a warm, low-scale, and residential feel. "The garages are integral to the success of this specialized mixed-use development," he says. The center incorporates banking, retail, condominiums, apartments, luxury hotel, fitness center, office space, and restaurants. "The garages includes dedicated areas for these groups, separating the residential parkers from employees and visitors."

Redevelopment Catalyst

Parking facilities can go beyond providing an attractive, functional facility to being a pivotal part of revitalizing a neighborhood. "Many designers give no thought to the foot traffic that a parking structure generates," he says. "In fact, parking can be the catalyst for redevelopment." Many times, attempts to revitalize an area fail because not enough thought was put into providing sufficient parking facilities, which visitors require to frequent a development. "Parking has to integrate with retail areas, or the retail won't succeed."

The Channelside District parking structure in Tampa, Fla., is an example of how parking can encourage growth. Officials at the Tampa Port Authority recognized the need to provide more parking infrastructure as the district's popularity as a dining and entertainment center grew. The design-build project, a $13.39-million horizontal

High performance and durability were requirements for the Channelside District parking structure in Tampa, Fla., situated along a Tampa Bay inlet. The facility was designed to encourage more visitors to come to the popular dining and entertainment district.

expansion of existing facilities, continues the original aesthetic design while enhancing the streetscape with textured screening over the precast concrete structure, plus vibrant lighting features and landscaping.

Aiding the versatility of parking designs is the way in which precast concrete can be shaped and blended with other materials to create exciting, durable structures. "Designers in the Northeast are very big on precast concrete due to the short construction season and durability of the material" he says. "It's faster to build with precast concrete."

Haahs has tried a variety of new techniques, including corrosion inhibitors and carbon-fiber reinforcement. But precast concrete's durability already is a plus. "Precast concrete provides high strength due to the fabrication process. We commonly find compressive strengths of 6,000-psi, or higher whether we need it or not. That creates a very durable structure. With cast-in-place concrete, we often fight to reach 4,000 psi."

As the industry evolves, so does his firm. It opened its first regional office in Miami in 2005, followed by two more openings in Atlanta, Ga., and New Brunswick, N.J., four years later. A Jacksonville, Fla., office opened in 2014. In 2012, the firm expanded its international practice with work in China, South Korea, and the Middle East.

Haahs' Best Practices

TimHaahs was first named one of The Best Places to Work by *Structural Engineer* magazine in 2007, and its programs to encourage growth among employees have grown since then. They include:

- TimHaahs University, which offers required and elective courses to employees on key issues.
- Pathway to Principal, a mentoring program that promotes leadership qualities in employees.
- Tuition reimbursement for relevant classes at local universities.
- The Extra Mile Award for outstanding service.
- Annual company retreat.
- TimHaahs Improvement Memo (T.I.M.) program, which ensures suggestions receive quick resolution and implementation.
- A variety of charitable-donation programs and support for various organizations.

Haahs also has spoken to a variety of groups, including the United Nations Economics and Social Commission for Asia and the Pacific.

"Our expansion is a direct result of what I went through," says Haahs, who had to undergo a second heart transplant in 1997 ("a perfect match"). "I learned I had to keep moving and growing, so when opportunities arose I took them. The new offices opened when clients told us they wanted us to work in those areas."

No matter where the industry moves in the future, Haahs will continue to focus on improving cities through educating his clients that parking should remain a key part of the planning. "The widespread success of town centers today is attributable to their ability to provide people with an exciting place to live, work, and play," he says. "Parking has and will continue to play a critical role in that success, providing essential infrastructure while creating a vibrant sense of community that so many people desire."

For more information on these or other projects, visit www.pci.org/ascent.

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Precast's Versatility Aids Parking

As parking needs expand, designers are looking to high-performance precast concrete to optimize aesthetics, speed, service life, and sustainability

— Craig A. Shutt

More demands are being made on parking structures today, as developers try to attract more people to more congested locations—and generate more revenue from the facilities. Attractive designs, whether blending with historic neighbors or creating a dramatic statement, are becoming the rule. Owners also are looking to add function by adding retail or building mixed-use properties atop the parking structures. They also are fitting them into tighter spaces with more activity around them. To solve these challenges and more, designers often turn to precast concrete solutions.

The following examples show some of the ways designers are using precast concrete's aesthetic versatility, sustainability, durability, resiliency, speed of construction, site efficiency, and other attributes to meet the growing challenges they face in designing parking structures.

The Z

A 10-story, mixed-use property in Detroit, Mich., tasked with revitalizing the city's historic Broadway district, The Z features retail, restaurant, and office space along with a 1,282 parking structure. To support these activities, designers planned a precast concrete parking facility with the goal of "creating a 'parking experience' atypical of the usual parking options in a major city," explains Joel Smith, principal at Neumann/Smith Architecture.

They accomplished this by designing a precast concrete façade with trapezoid-shaped spandrels that create large, dimensional windows along its length and horizontal openings that band the structure. Additional lights and accents create picture-frame designs that are reinforced on the interior with a series of murals that enliven each floor of the building.

The intention was to create the coolest parking deck ever," he says. "Parking decks are typically more functional in nature and less focused on aesthetics. Our goal was to ensure the parking deck didn't look like a parking deck." That focused in part on hiding the ramps so the building didn't reveal that it hid 10 floors of sloping surfaces. The team designed bold geometric cut-outs for the façade panels that replicated the look of windows. Each "window" spans two floors and was lined with LED lights to provide a bright, eye-catching outline that invokes the image of picture frames.

The structure features a total-precast concrete structural solution, including double tees, columns, inverted tee beams, ledger beams, spandrel panels, stair and elevator walls, shear walls, bollards, solid planks, and other components. A variety of finishes were used, including hard steel-troweling on interior shear walls, white sandblasted architectural spandrels, stained columns, and spandrels with a medium sandblast. Kerkstra Precast Inc. fabricated the precast concrete components.

"Precast concrete helped create the modern and clean, smooth and fluid look," he says. The façade was created with a bright white mix, which blends with neighboring buildings finished in white terra cotta. The bright color also served as a canvas for 27 world-renowned street muralists, who created artwork inside the building. The goal was to create a "museum" within the precast concrete walls, with the murals representing what they meant to each artist. "The experience is like driving through an art museum, discovering a little piece of the city on each floor."

The "picture-frame" effect on the building's exterior was created with trapezoidal infill pieces, which were clipped in place to the vertical columns. The design team originally explored the use of applied metal-skin panels, clipped to the structure, but this approach proved too complicated and expensive. "This way, the façade could be fabricated entirely and precisely by a single source," he says.

The spandrels and columns were erected to support the double tees, while the trapezoidal infill pieces clipped onto the spandrels, minimizing movement of the crawler-crane. Sliding connections allowed the panels to be precisely aligned to a high tolerance. "That was essential on such a crisp design," he says.

Casting Efficiencies

The same floor slope was used on both street elevations of the deck to minimize the number of unique pieces that had to be cast. In some cases, forms were reused for pieces that were inverted for use on opposite sides of the building, reducing formwork and saving time. A full-sized, foam mock-up of a typical bay was created to validate the design and installation; to benchmark the installation process; and to validate the jointing, piece lift points, and load bearing conditions.

The building spans an alley with

The Z, a 10-story, mixed-use property in Detroit includes a 1,282-car precast concrete parking structure designed with "picture-frame" style windows made with trapezoid-shaped spandrels and horizontal openings that band the structure. Additional lights and accents highlight the exterior, while murals enliven the interior. Photos: Neumann/Smith Architecture.

PROJECT SPOTLIGHT

The Z

Location: *Detroit, Mich.*

Project Type: *Parking structure*

Size: *535,000 square feet*

Designer: *Neumann/Smith Architecture, Southfield, Mich.*

Owner: *Bedrock Real Estate Services, Detroit, Mich.*

Structural Engineer: *Rich & Associates Inc., Southfield, Mich.*

Contractor: *Colasanti/Sachse JV, Detroit, Mich.*

PCI-Certified Precaster: *Kerkstra Precast Inc., Grandville, Mich.*

Precast Specialty Engineer: *IES Associates Consulting Engineers, Windsor, Ontario, Canada*

Precast Components: *Total-precast concrete structural system, including double tees, columns, inverted tee beams, ledger beams, spandrel panels, stair and elevator walls, shear walls, bollards, solid planks, and other pieces.*

crossovers located at level three, allowing users access to two major arteries into the city. It also uses its glass-enclosed corner stair towers as key landmarks for the building, working as "lanterns" on the block, he says. "They work as place-markers and main wayfinding elements that provide constant light and a sense of security." Each landing has bright-white LEDs and walls painted with a designated color. The exterior corners of the building are lined with vertical RGB LED lights with 16 million possible color combinations, changed to celebrate holidays and special events.

The erection moved smoothly, despite the building being fit in among a variety of existing structures. "Special attention was paid to the proportions of the building so it filled in the gaps between buildings but maintained an appropriate scale for the block," he says.

The team originally thought rigid insulation would have to be added within the panels to reduce the weight for lifting as well as to minimize the foundation load. But they calculated that by panelizing the picture-frame elements and optimizing panel sizes, they could maintain the limits for lifting and retain the panels' aesthetics while reducing costs. "We saved money because there was no need for another trade to finish the exterior of the building or for another mobilization," he explains.

Meeting schedule and budget was critical, he notes. "This parking deck is the owner's first ground-up project and the largest new-construction project in the city in a number of years, so the publicity that surrounded it put pressure on the team to get it right." The precast concrete was produced, shipped, and erected rapidly and within budget, to the extent that the owner saved enough money that amenities were added, including the murals and painting the interior.

The result is a dazzling structure that stood out to the judges in the 2014 PCI Design Awards competition. They gave it the award for Best Parking Structure. "The creation of this iconic design was made possible by the flexibility of precast concrete, utilized in this unconventional application," he says.

City Center

The six-level, 524-car precast concrete parking structure at the City Center Development in Columbia, S.C., transformed a low-density surface parking lot in an urban, historic area into a high-density infill project. "The building completed the street corner in accordance with the downtown context and evokes an architectural expression that responds to nearby office and retail buildings," explains Jason Likas, project manager for LS3P Associates Ltd., the architectural firm on the project. It includes retail space on the first floor along the street to promote activity and generate interest.

The building's façade features a variety of masonry materials, including cast-stone blocks but especially thin brick, cast into architectural precast concrete panels to blend with the neighborhood. "As brick is the dominant material on the surrounding historic structures, the design incorporates a predominant amount of brick combined with other materials," he says.

"Great attention was given to the brick detailing and structure to create the timeless aesthetic. The precast concrete approach allowed for more flexibility in the design of the façade, as the construction process is more controlled in the plant, providing more flexibility in the level of detail and arrangement of precast concrete pieces to meet the aesthetic goal."

The structure features a total-precast concrete framing system, including double tees, beams, columns, spandrels, fascia, Metrowalls, flat slabs, shear walls, and architectural panels.

"Our goal was to integrate a wide range and mix of materials, including different types of stone and masonry as well as aluminum, steel, and glass," he says. "Having the flexibility to implement a large range of materials, specifically glass, allowed for a 'see and be seen' environment at the stair towers especially, increasing passive security."

The openness of the parking structure was enhanced by the precast concrete design, he notes. "With the immediate adjacency of the existing building to the west and the desire to mimic the façade of the garage to that of the surrounding office buildings, obtaining the appropriate level of openness was a challenge."

Long vertical exterior façade panels with blockouts allowed the design to mimic the appearance of office windows while providing more control of the percentage of openness. Finishes were also kept to a horizontal pattern around the perimeter to mask the sloping floors behind the façade. "The longer beam spans provided greater flexibility and allowed for more openness to the overall structure."

Openness was enhanced further by pushing the building's shear walls to the exterior, maximizing internal sight lines for users at critical locations. "Internal openness was achieved without adversely affecting or limiting the design of the exterior aesthetic thanks to the flexibility in design that precast concrete provided."

Bay Window Created

One design element that combined aesthetics and openness was the large "bay window" added at one corner of the façade. The buff-colored spandrels cantilever off the frame and provide a three-sided window unit with lintel. "Cantilevering the structure beyond the face of the building creates depth and provides a focal point at the intersection," he explains. "The detailing of the unit was unique and an atypical element. Creating it while maintaining the appropriate vehicular and pedestrian restraints was challenging."

The building also features the first enclosed stairwells in the city for a public parking structure. The design plays this up by accenting the stair/elevator towers with glass curtain wall and spandrel panels that allow natural light to flood into the area. "It promotes a sense of visibility and security." Wayfinding was enhanced with colorful, curved, hanging ceiling features on each level. Sunshades also were placed on the south side along the tenant spaces and stair tower.

Designing and erecting the structure on the site also offered a challenge.

To achieve the full footprint that city officials desired, they purchased an adjacent property and demolished it. "The building had to optimize the number of spaces available and generate interest for customers and passers-by," he explains. Field-topped double tees were used to minimize joint widths at the tee-to-tee interfaces to reduce noise and vibration for the retail spaces on the first floor.

The site constraints required short ramps, as vertical vehicular circulation space was limited, he adds. Typically, a minimum of 165 feet is needed to obtain an 11-foot floor-to-floor height with accessible parking on the ramps, but the structure offered only 145 feet. To achieve the proper slope, the double tees in the end bays at each end of the ramp were dapped at different depths to create an additional 8 inches of vertical height over the inverted tees.

This technique resulted in an additional 16 inches in total vertical height gain per 360-degree revolution on the ramps, effectively lengthening the structure by about 20 feet. That extra space ensures all of the ramps can provide the maximum amount of parkable space, increasing efficiency. It also allowed exterior bays to remain relatively flat along the north and south sides of the deck (with slopes in those bays for drainage only), providing a more horizontal appearance. Enhancing the appearance further, the ramps were cast with a higher quality finish on the underside to provide more light reflectivity to brighten the ramp area.

The site was surrounded by streets and adjacent buildings, minimizing the available area for laydown space. The precast concrete elements were cast at the plant, delivered to the site, picked from the trucks and set immediately into place. "The contractor did not require space to store reinforcing steel, tied reinforcing cages, formwork, etc." Erecting precast concrete components also minimized the potential for damaging the adjacent historic structures due to vibrations associated with typical construction activities, he notes.

Local requirements limited the location and orientation of the

Cast stone block and thin brick were cast into the architectural precast concrete panels cladding the six-level, 524-car precast concrete parking structure at the City Center Development in Columbia, S.C. It helped transform a low-density surface parking lot in an urban, historic area into a high-density infill project. Photos: LS3P.

PROJECT SPOTLIGHT

City Center Development Parking Garage

Location: *Columbia, S.C.*

Project Type: *Parking structure*

Size: *184,397 square feet*

Cost: *$11.3 million*

Designer: *LS3P Associates Ltd., Columbia, S.C.*

Owner: *City of Columbia, Columbia, S.C.*

Structural Engineer: *Kimley-Horn and Associates, Raleigh, N.C.*

Contractor: *Contract Construction Inc., Ballentine, S.C.*

PCI-Certified Precaster: *Metromont, Greenville, S.C.*

Precast Specialty Engineer: *Starnes Chambers & Associates, Rock Hill, S.C.*

Precast Components: *A total-precast concrete structural system, including double tees, beams, columns, spandrels, fascia, Metrowalls, flat slabs, shear walls, and architectural panels.*

The new three-level, 249,484-square foot, precast concrete parking structure at the Regional Transportation District (RTD) station for Jefferson County was designed to maintain the aesthetic design of the nearby judicial center, using colors, acid-etching, and exposed aggregates. Reveals were placed to mimic the gridded pattern found on the existing campus. Photos: IBI Group.

PROJECT SPOTLIGHT

RTD Jefferson County Parking Structure

Location: *Golden, Colo.*

Project Type: *Parking structure*

Size: *249,484 square feet*

Cost: *$12.5 million*

Designer: *IBI Group, Denver, Colo.*

Owner: *Regional Transportation District, Denver, Colo.*

Structural Engineer: *Martin and Martin, Lakewood, Colo.*

Contractor: *Hyder Construction Inc., Denver, Colo.*

PCI-Certified Precaster: *Stresscon Corp., Colorado Springs, Colo.*

Precast Components: *A total-precast concrete structural system, including double tees, inverted tee beams, columns, and pedestrian bridge tees, K-frames, hammer-head shear walls, litewalls, architectural wall panels and spandrels.*

foundations, requiring all of them to be eccentric to the columns and walls. That allowed no foundation projection beyond the face of the structure. "Typically, that would result in large eccentric loads to the foundations, significantly increasing the size of the footings around the perimeter," he explains. Using precast concrete components more easily allowed the designers to create a "pinned" connection at the base of the columns, eliminating the load transferred to the foundations in a lateral-loading event. That configuration reduced the load required through the foundation and reduced the impact of the eccentric columns.

The precast concrete design also sped up construction, ensuring a timely opening for the project. "Utilizing precast concrete allowed for a faster overall project schedule, which minimized the duration of the disruption downtown. It also eliminated the need for concrete mixers and pump trucks to block lanes during the busy daytime hours or overnight." That also minimized late-night noise at the site, which can invoke complaints from nearby tenants.

"Precast concrete was an integral of the design," he says. "It not only enhanced the overall appearance of the building, but it provided the essential structural elements to support the structure.

Jefferson County RTD

The new Regional Transportation District (RTD) parking structure for Jefferson County is located on the campus of the Jefferson County Judicial Center in Golden, Colo. The facility serves the western terminus station of the RTD-Fastracks-West Corridor light-rail line and parallels the 6th Avenue freeway that links Golden to downtown Denver at the new Union Station hub.

Officials knew they needed a striking design for the parking structure that did not detract from the scenery at the foothills of the Rocky Mountains. They also needed it constructed quickly to ensure it was ready when the adjacent train station was completed, as the station was situated on some of the original surface parking lot used by Jefferson County staff.

"Keeping with the theme of the judicial center, the architectural precast concrete used on the façade maintains the colors, acid-etched finish, and exposed-aggregate textures of the existing campus architecture," explains Peter Zurawel, regional director for IBI Group, the architect of record on the project. Reveals were placed to mimic the gridded pattern found on the existing campus buildings as well. "The warm tones available with precast concrete made it an easy choice to match the nearby sandstone outcroppings in the area," he adds.

The new three-level, 249,484 square-foot structure accommodates 822 cars. The precast concrete framing system features double tees, inverted tee beams, columns, and pedestrian bridge tees, with K-frames and hammer-head shear walls for lateral stability. Precast concrete litewalls along the ramps provided both gravity and lateral loadings along with openness for patron visibility and air circulation. The structure's perimeter is clad with architectural precast concrete wall panels and spandrels. Stresscon Corp. fabricated the precast concrete components for the project.

Precast Concrete Tunnel

At the sound end of the structure, the precast concrete framing was designed to create a tunnel for the light-rail train to pass through before reaching the boarding platform, adding some drama to the design. Adjacent to the south side of the facility, a precast concrete pedestrian bridge provides safe passage over the rail lines, maintaining an uninterrupted path for pedestrians. At both locations, precast concrete tee depth was minimized to ensure required clearances were maintained for the trains below.

Precast concrete's inherent nonconductivity eliminated the need for shielding from the high-voltage catenary wires powering the trains. Using precast concrete also simplified the required fire separations between train tunnel and the rest of the parking structure.

To further blend the structure with its surroundings, the spandrels feature a metal green screen attached to them that allows native landscaping to climb the façade, reflecting the experience of the surrounding foothill environment.

The design met all of the owners' functional, aesthetic, schedule, and budgeting goals, Zurawel says. "The owner likes the durability and low maintenance associated with the precast concrete structure."

The building was sited to tuck into the landscape at the front of the Justice Center, minimizing the impact of the primary view to the center itself and the surrounding hills. Precast concrete panels were used to construct the below-grade, retaining-wall system, expediting their construction so site work could begin. The precast concrete components took about four months to erect.

The structural versatility of the precast concrete panels allowed for corner glazing around elevators and stair towers, which met the owner's requirement for maximum visibility into the vertical-circulation elements, emphasizing user safety. It also created a signature touch that ensures the building doesn't disappear from user's sight as they approach, Zurawel notes. "In the evening, the brightly lit corner towers act as beacons, notifying the public of the location at the entry to the campus."

University of Houston

The University of Houston needed to expand its parking facilities near its athletic fields and to accommodate an expanded program that drew more students, most of whom commute. But it also wanted to add excitement and create a signature look to the facility, which would be located at a gateway to the campus. To meet all of these goals, designers created a total-precast concrete structure with decorative, school-themed flourishes and a retail walk along the side of the building facing the stadium.

The facility was built on a surface parking lot on the edge of campus, adjacent to the stadium and near where a new light-rail station was being built. As a result, speed was of the essence, says Marie Hoke, principal in charge at WHR Architects. "Any time you have to take parking off-line, it becomes a matter

PROJECT SPOTLIGHT

University of Houston "Cougar Walk" Parking Structure

Location: *Houston, Tex.*

Project Type: *Parking structure*

Size: *700,000 square feet*

Designer: *WHR Architects Inc., Houston, Tex.*

Owner: *University of Houston, Houston, Tex.*

Structural Engineer: *Walker Parking Consultants, Houston, Tex.*

Contractor: *Vaughn Construction Co., Houston, Tex.*

PCI-Certified Precaster: *East Texas Precast, Hempstead, Tex.*

Precast Components: *A total-precast concrete structural system, including double tees, columns, beams, shear walls, litewalls, stairs, and architectural load-bearing panels.*

The new University of Houston parking structure adjacent to the school's athletic stadium features a "Cougar Walk" (which is the name of their sports teams) of shops along the side facing the stadium and a pedestrian ramp that cantilevers from the precast concrete structure to provide quick access for users. Mesh screening with the schools' logo creates a signature look for the building at a gateway to the campus. Photos: WHR Architects.

of speed to replace it before things get problematic. We specified the precast concrete structure due to the very tight schedule and also because it was the most economical approach."

The 2,200-car structure, covering about 700,000 square feet on four levels, offers a long rectangular footprint that provided a long façade on which to front retail, creating a "Cougar Walk" (which is the name of their sports teams) of shops aimed at attracting game-day shoppers and showcasing athletic merchandise. But that side and the parallel side presented 750-foot-long faces that needed to be visually reduced in size.

"We used a variety of textures and aesthetic treatments to break down the scale of the very long sides," Hoke explains. "We didn't want to mix colors within a panel, as we knew that would add cost, but we could vary the textures within a panel. So we used several textures and reveals to create a change in lighting and shadows throughout the day."

The base panel look was created with a limestone aggregate with a buff color and medium to heavy sandblast, creating two mix designs. Thin lines of reveals, which create ribs of a rougher texture, were created with chamfers in the forms. "One of the great things about precast is its versatility to use multiple ways to achieve the same goal," notes Chris Romani, sales and marketing manager for East Texas Precast, which fabricated the precast concrete components. "This design could be achieved by a formliner or chamfers, but for this specific project it was determined that chamfers was the more efficient method.

Openings in the façade also were varied, with tall punchouts used on the first level and square openings provided on two upper levels (with additional parking on the roof). "The panels were erected vertically, which made varying the openings in size easier to work with," says Jeff Chittenden, senior project architect at WHR. The panels were load-bearing, which limited the shapes of the openings, as they couldn't interfere with the columnar load capacity. Reveals were added at key points to attract the eye and break up the masses further.

"Adding punchouts into the panels isn't as difficult as might expect if you have an exact plan and efficient panel sizes," explains Romani. "The key was to meet the small tolerances that were required, especially for vertical panels."

The façades were further enhanced with tall, post-applied vertical aluminum box fins that serve as banners to add dimension and draw attention to entry points. These were specified in Cougar red to make them stand out and announce the university's presence. The fins and awnings along the Cougar Walk were attached to the precast with tubing that was welded onto embeds in the precast panels, explains Mike Stites, operations manager for East Texas Precast Erectors, which erected the precast concrete.

Stairway Provides Landmark

The main stair tower was pulled outside of the building's footprint to ensure it didn't eliminate any parking spaces. This positioning was taken advantage of by covering its side with a perforated-metal screen with the university's logo attached to it.

On the side facing the stadium, an exterior pedestrian ramp funnels users to the stadium and back again, creating faster traffic flow. The ramp cantilevers off the structure outside of the parking footprint. "We were tasked with creating a 20-minute dump time, which is the time it takes to empty all cars from the structure. When this was coupled with the tight dollars per space and other requirements, created a number of challenges."

The structural system consists of precast concrete components, including double tees, columns, beams, shear walls, litewalls, stairs, and architectural load-bearing panels.

A waterproofing membrane was provided above the retail spaces to protect them from inclement weather, and a drainage system was added as well. "There is a lot of redundancy in the system throughout, especially for the waterproofing," says Chittenden. Three-foot-wide metal troughs were located beneath joints in the double tees that channel any water leaking through to drains. "It adds extra protection to the design."

One challenge developed after design had commenced, when office space had to be added to the first floor. "We agreed to add it and then learned that the space needed to be 5,000 square feet," says Hoke. "We didn't have that much space available that would still allow us to meet the parking needs." Space was carved out beneath the express ramps, and it then had to be insulated to control noise in the area.

Erection moved smoothly, in part due to the open space in the area. Even so, the busy campus required close cooperation to minimize transportation issues and site congestion. "Logistically, there were no issues with setting the crane wherever we needed," Stites says. Two cranes were used to speed erection, with one road providing access coordinated with construction at the nearby light-rail station.

"It was a pedestrian-rich environment, so we wanted to be in and out as quickly as possible," adds Stites. The vertical panels were designed with no wall-to-wall connections on the long sides of the structure, he notes. "It was an independent system with tees, columns, and beams, which saved all kinds of time and increased our speed." The entire project was erected in three months.

The result is a highly functional building that serves students during the week and game-day fans on weekends, with added excitement from the embellishments and retail spaces. "We had an opportunity to integrate a row of retail shops into the stadium side, which created a mixed development and added excitement," Hoke says. It also helps generate revenue and identify the parking as a university building at the entrance to the campus.

These projects show the diverse ways that precast concrete's versatility, speed, efficiency, and resiliency can aid parking projects of all types. Whether they are in tight urban locations or more open spaces that will serve as signature gateways, parking structures gain a variety of benefits by using a precast concrete structural system and architectural panels to achieve functional, budgetary, aesthetic, performance, and scheduling goals.

Winning Design

Saint Leo University adds significant parking space by moving existing lacrosse field to new facility's rooftop supported by Florida bridge tees

— Craig A. Shutt

Administrators at Saint Leo University in Saint Leo, Fla., faced a challenge typical to many colleges. While academic programs were expanding and the student population growing, the school's land area could not be increased to supply more parking facilities. To meet these needs, the design team appropriated a lacrosse field, extended the space by cutting into an adjacent hillside, and created a 150,000-square foot precast concrete parking structure on the site. They then restored the lacrosse field by placing it on the parking structure's roof.

The $12.7-million project abuts wetlands that served as a prime driver for the design of the structure. Building against the hill and down a slope to the wetlands proved challenging, especially with several levels dug below grade to avoid raising the structure and pushing the proposed rooftop lacrosse field too high into the air. But the results proved to be worth the effort.

"We wanted the parking structure to blend seamlessly into the campus grade," explains Edward Lunz, principal at Lunz Prebor Fowler Architects. Indeed, except for the stair towers and stadium profile, only the top of the athletic field is visible from the entry. Landscaping on three sides and on the pedestrian paths create a park-like view to the wetlands beyond.

Florida Bridge Tees Used

The structural precast system (sometimes referred to as total-precast) features 8-foot wide by 37-inch-deep Florida bridge tees, as well as traditional prestressed double tees, exterior and interior columns, beams, vertical lite walls, shear walls, several types of spandrels, stairs with landings, slabs, and wall panels.

In addition to the parking facility, 1,000-seat seating sections, concessions, and ticket-taking facilities were built with precast concrete components as standalone structures adjacent to the parking, aligned with the rooftop field. "Building these facilities as separate structures allowed both projects to be constructed at once, and designing all with precast concrete allowed for faster construction," Lunz explains.

The use of precast concrete for the structure resulted from the decision to add the FIFA-rated/NCAA-regulation lacrosse field to the roof. Saint Leo is now one of only three universities in the country with a rooftop field. "The main challenge was budgetary considerations," Lunz notes. "The innovative idea of locating the field on top of the garage required a judicious approach to the budgetary constraints." Shifting funds to allow for the field's creation required "a streamlined and efficient structure," he says.

"Additionally, the timing was tight and an accelerated schedule was requested." The schedule demands were driven by a need to complete the lacrosse field in time for the following year's season. "Precast concrete was the only logical solution that combined the desired cost effectiveness with the structural accommodations for parking, life-cycle cost, and long-term durability."

The Florida bridge tee was specified due to the heavier loads required for the rooftop level. The loads were further increased due to the university's desire to use the field for graduation ceremonies. "Those tees typically are used for bridge projects, but the 60-foot narrow tee design provided the load capacity that would be needed," explains Mark McKeny, sales manager for Coreslab Structures (Tampa) Inc., the precaster. "We had to account for the soil and turf dead load of 300 psf plus 150 psf live load for the assembly area."

The tees were cast with self-consolidating concrete, which typically provides 7,500 psi strength at 28 days. "The sections were deeper and heavier than would be typical to ensure we could support the rooftop loads," says Mark Cerminara, vice president and general manager at Salmons PC, the precast concrete specialty engineer.

Retaining Wall Placed

The precast concrete components were cast while the site was prepared. The site required considerable work, as a two-story slice of the hill had to be excavated. A 25-foot, cast-in-place retaining wall was built along one long side of the building to hold back the grade. The concession and seating sections were built against this wall. The soil was hauled away with off-road dump trucks and placed in a bowl-shaped site on campus to move it out of the way until it could be removed. "There was a tremendous amount of dirt that had to be moved from the site," Lunz says.

The retaining wall connects to the façade of the parking structure, requiring corbels to be placed precisely. "It's not really an unusual design, but it had to be coordinated closely," says Cerminara. "It created challenges in tolerances, and it required stronger connections to accommodate the heavier roof loads."

At the same time soil was being excavated to provide two below-grade levels to reduce the building's overall height. This placed the entry at mid-level, with one parking level below the entry and the lacrosse field above. A kiosk sign with a parking-space counter at the main entry guides patrons to open parking and indicates when the facility is full. Two-way, 60-foot clear bays, and four bays with one, two-way ramp down to the lower level ease congestion.

"We dug down because we wanted to make the project as environmentally friendly as possible and enhance the landscape," says Lunz.

Photo: Lunz Prebor Fowler Architects.

PROJECT SPOTLIGHT

Saint Leo University Parking Structure

Location: *Saint Leo, Fla.*

Project Type: *Parking structure*

Size: *150,000 square feet (275,000 square feet including adjacent supplemental facilities)*

Cost: *$12.7 million*

Designer: *Lunz Prebor Fowler Architects, Lakeland, Fla.*

Owner: *Saint Leo University*

Structural Engineer: *Master Consulting Engineers, Tampa, Fla.*

Contractor: *Creative Contractors Inc., Clearwater, Fla.*

PCI-Certified Precaster: *Coreslab Structures (Tampa) Inc., Tampa*

Precast Specialty Engineer: *Salmons PC, Phoenix, Ariz.*

Precast Components: Florida bridge tees, prestressed double tees, exterior and interior columns, beams, vertical lite walls, shear walls, several types of spandrels, stairs with landings, slabs, and wall panels.

The new precast concrete parking structure at Saint Leo University in Saint Leo, Fla., was built adjacent to a wetlands and features a lacrosse field on its roof. Precast concrete concession stands and seating were built next to the parking as standalone structures. They feature the campus' signature Mission style.

Photo: Aerial Innovations.

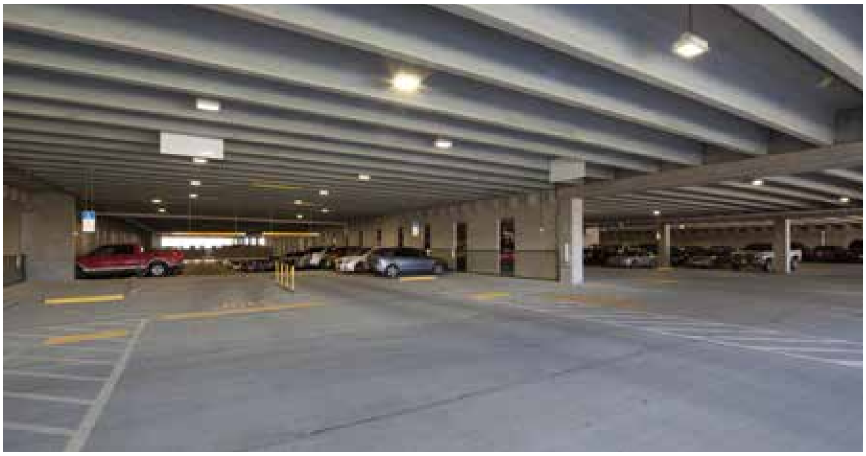

Photo: Lunz Prebor Fowler Architects.

"It's a beautiful site, and we didn't want to block views to the wetlands and wooded areas if we didn't have to. We also wanted to ensure the lacrosse field remained accessible to pedestrians."

Vehicular wayfinding was provided with reflective stop bars and floor arrows, as well as reflective signage attached to the bottom of double tees. Pedestrians access the top-level field and main campus from stair towers at each end of the structure on all levels and at the main entry.

Three Fields on Roof

The rooftop fields required significant work once the bridge tees were erected. In all, three fields were built on the roof, including two practice fields placed perpendicular to the main field and striped for student use. The main field features artificial turf, although it was designed to allow a change to natural turf if desired, Lunz notes. "They wanted it to be able to support loads for graduations, when thousands of people might walk over it or sit on the field, so allowing a change to natural turf in the future wasn't difficult to factor in."

Creating drainage for a sports field on the roof added challenges, says Salmons' Cerminara.

"We had to consider camber on the tees and allow for the loads during any point in time. The field will not always have the heavy live load, so we had to allow for excess camber so natural drainage will be provided. We had to balance all of the loading needs at different times and calculate the optimum slope."

The field slopes from east to west with a trench drain at the end to collect water and direct it to a detention pond at ground level, where it is treated and released into the wetlands. To protect lower levels from a buildup of water, a burlap waterproof membrane was added over the tees, as well as a layer of rock. The rock had to be trucked in and moved by escalators onto the roof from the sides. "It was a pretty complex process," notes Coreslab's McKeny.

Mission Style Featured

The structure and adjacent facilities feature a Mission-style design, a predominant theme throughout the campus. This motif was designed into the structure—notably at the stair towers—and was also used on the standalone structures. Some of the curved shapes were cast into the precast concrete using formliners, while others were added after erection with stucco. The precast walls were painted gray after erection to match the color of the other buildings on campus.

"The Mission style is a hallmark of the campus, owing to the original abbey on the site," Lunz explains. "Using precast concrete gave us a much more durable surface to work with in creating some added touches." No special forms were needed to create the design, he adds.

'The Mission style is a hallmark of the campus, owing to the original abbey on the site.'

High lighting fixtures, towering 40 feet above the field, were needed to provide illumination for night-time activities. These fixtures were placed on heavy-duty, 32-inch-square precast concrete columns that serve as the bases. "They're much larger than would typically be provided for a parking structure," McKeny says. They also required 4-foot-long anchor bolts to be cast into the columns to secure the fixtures.

Fabricating the precast concrete components off-site minimized site congestion, a key requirement with so much campus activity nearby. The school gymnasium and baseball stadium were adjacent to the parking structure, along with existing surface parking areas. The construction also had to contend with a great deal of pedestrian traffic in the area. "It was a lot of activity, so we had to carefully plan our activities and minimize disturbances, especially as we were building next to the wetlands," Lunz says.

The precast components were cast and staged at a nearby site off-campus, McKeny notes. One traffic lane was provided to bring trucks in and out, the components were picked from the trucks and erected immediately. "Our goal was to avoid any traffic congestion or to interfere with activity on the campus in any way."

LEED Standards Met

The building was designed to meet LEED standards but was not submitted for certification. "We've designed other LEED buildings for the university, including one that achieved Gold," Lunz explains. "But for budgetary reasons, the university wanted the structure to comply with LEED but didn't want to spend the money on the application fee."

With the concession and seating areas placed along the side containing the retaining wall, the design offered three open sides for the interior parking levels, creating light, bright openings for daylight, Lunz says. In addition to 730 car spaces, there are 24 motorcycle and bicycle slots. Twenty golf-cart charging stations are located in the lower level. This amenity allows university personnel to park their cars and pick up a cart to get around campus, reducing vehicular traffic. Another 6,000 square feet of storage space was provided under the ramps to house the building's sprinkler system and university property.

The result is a multifunctional building that adds to the existing facilities while providing considerably more function without disturbing the natural beauty of the area. It also offers options for future changes when needed. In addition to the possibility for switching to a natural-turf field, designers also allowed the potential for removing the field and creating another level of parking if that option is needed in the future.

The designers achieved the university's goal of fitting the structure into the landscape a little too well. They discovered that the building blended so well with its surroundings that first-time users had difficulty finding it. Signage was added to direct visitors to the entry. "The university was very pleased with the building," says Lunz. "It meets all of their functional and aesthetic goals, so having hidden it so well that signage was needed was a minor point."

The structure also provided an improvement on the existing field. The new fields are elevated 3 to 10 feet above the adjacent roadway. The variance results from the topography sloping toward the wetlands, which had caused problems for the previous lacrosse field. That difficulty was ironed out by the rooftop position, which could adjust to the topography and create a literal level playing field for all.

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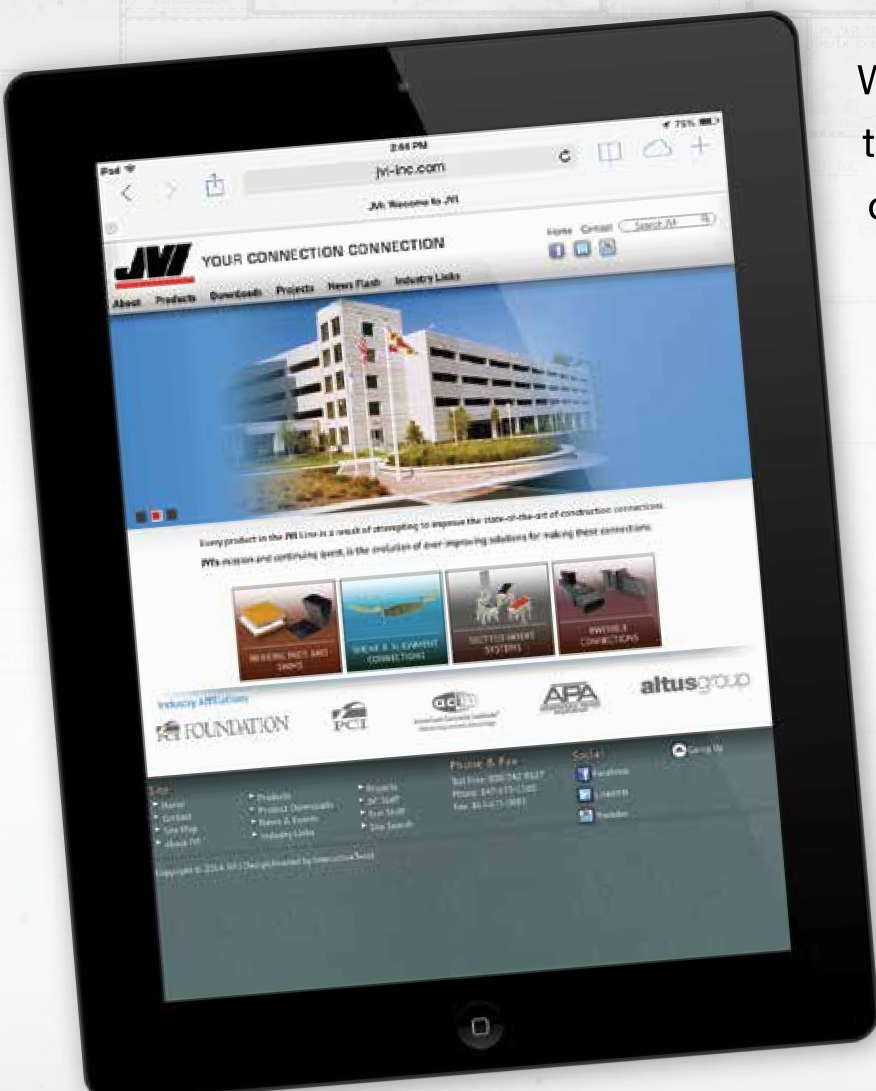

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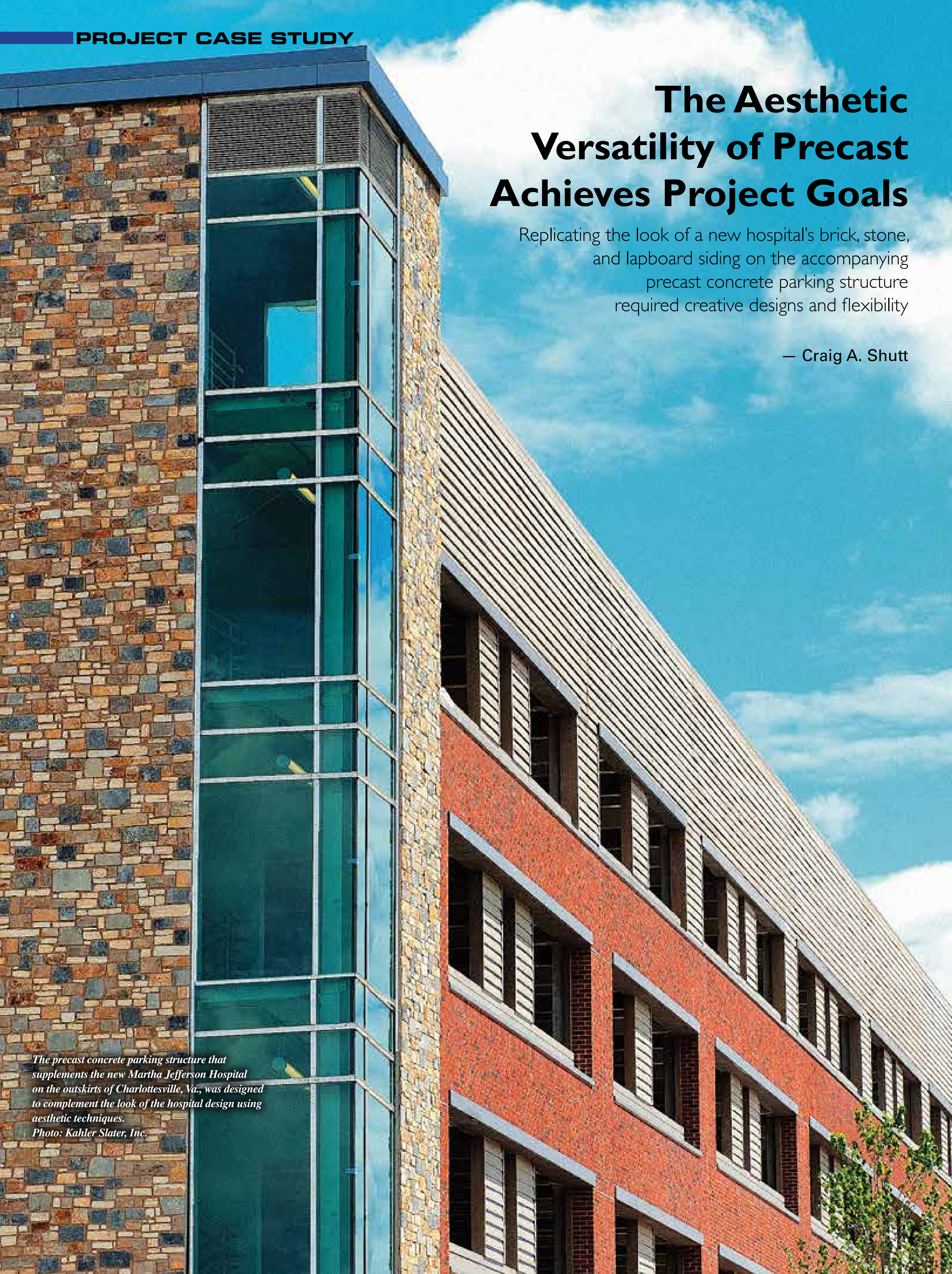
The Aesthetic Versatility of Precast Achieves Project Goals

Replicating the look of a new hospital's brick, stone, and lapboard siding on the accompanying precast concrete parking structure required creative designs and flexibility

— Craig A. Shutt



The precast concrete parking structure that supplements the new Martha Jefferson Hospital on the outskirts of Charlottesville, Va., was designed to complement the look of the hospital design using aesthetic techniques.
Photo: Kahler Slater, Inc.

The new Martha Jefferson Hospital on the outskirts of Charlottesville, Va., lies atop a hill in the sightline of Monticello, Thomas Jefferson's historic plantation. In such august company, designers wanted the new hospital to blend with the local styles, featuring masonry and lapboard siding with a slate roof. Those materials were specified to clad the hospital—and they were replicated on the adjacent precast concrete parking structure, creating unique replication challenges that showcased the material's aesthetic versatility.

'When we design parking structures, precast concrete is always our first choice, because it offers the best value in terms of cost, durability, and speed of construction.'

"The parking structure provided a unique challenge to match the hospital's traditional materials in precast concrete," says David Plank, associate principal and project architect at Kahler Slater. "When we design parking structures, precast concrete is always our first choice, because it offers the best value in terms of cost, durability, and speed of construction. We designed the hospital with the look we wanted, and we had enough faith in the local precasters that they could replicate the materials we used."

The buildings, part of the Peter Jefferson office complex, provided a new home for the hospital, which moved from downtown Charlottesville and prides itself on its historic preservation. Matching the parking structure to the new hospital's design in precast concrete could be achieved, but optimizing the panels to provide the precise look with the variety of materials required proved challenging, says Jim Lyons, project manager at The Shockey Precast Group, the precaster on the project.

Total Precast Structure

The structure features a total precast concrete structural system consisting of double tees, beams, columns, walls, stairs, and architectural spandrels. The structure itself was relatively easy to design, measuring three bays wide and six stories tall to provide the needed 765 spaces in the approximately 250,000-square-foot rectangular building. But achieving the appearance needed for each panel required careful attention to detail.

Surrounded in the complex by buildings with façades featuring brick and dark gray cast stone, the parking structure was designed to feature a dark brown wood siding look (achieved with formliners) as well as embedded cast stone and brick features. Brick was used primarily

PROJECT SPOTLIGHT

Martha Jefferson Hospital Parking Structure

Location: *Charlottesville, Va.*

Project Type: *Parking structure*

Size: *Approximately 250,000 square feet*

Designer: Kahler Slater, Milwaukee, Wis.

Owner: *Martha Jefferson Hospital, Charlottesville, Va.*

Structural Engineer: GRAEF, Milwaukee, Wis.

Contractor: *M.A. Mortenson, Brookfield, Wis.*

PCI-Certified Precaster: The Shockey Precast Group, Winchester, Va.

Precast Components: Total-precast concrete structural system, including double tees, beams, columns, walls, stairs, and architectural spandrels.

To replicate the look of the natural materials used on the hospital, the precast concrete panels cladding the parking structure feature three finishes and four concrete mixes. The inset brick added another texture and color to the aesthetic palette. Photo: Kahler Slater Inc.

Panels often had more than one texture in them to reduce piece counts. The dividers in openings, which offered a woodgrain appearance, added depth and a window-like appearance but required special attention during transportation. Photo: The Shockey Precast Group.

The precaster had to ensure each finish was contained with no spillover as the various textures were cast in the panels. Photo: The Shockey Precast Group.

on the lower floors, acting as a solid base, while cast-stone panels frame the glass-enclosed stair towers on the end. The wood siding appearance was used on upper levels and as accents for the windows and to frame the perimeter.

To achieve all of these variations, the panels feature three finishes and four concrete mixes: one each for the lap siding, cast-in lintels and sills, mortar around the inset brick, and the gray panel backup. The inset brick added another texture and color to the aesthetic palette.

Complicating the design further was the need to match the bricks on the adjacent hospital, but no thin brick provided the proper appearance. To resolve this issue, the precaster bought full bricks from the local manufacturer and sliced off the front half to insert into the panels. "We needed to slice each brick thin enough and consistently across all of them to fit uniformly into the panels," Lyons explains.

Using the full bricks, while more time-consuming to produce, provided a key benefit, notes Plank. "Because we had full bricks at our disposal, we could do full corners with returns at the punched openings and set them back deeply. They look quite sharp." Lintels that accent the openings, which provide the appearance of windows, project out from the panels, while wood-like vertical dividers that split some openings were recessed to provide depth and more shadow lines.

Panel Sizes Optimized

Many of the panels combined a variety of colors and textures to help reduce the total number of panels. These are often referred to as combination finishes. "It was a complicated system, but it greatly simplified the job on-site," says Lyons. Optimizing the sizes without regard for the number of textures and colors in each panel cut the piece count by more than 100. "That reduced shipping and erecting costs significantly." The typical panels were 1 foot thick, 48 feet long, and 9 feet tall, weighing approximately 50,000 to 60,000 pounds.

As the combinations were designed and formliners, textures, and embedded brick were aligned, the key concern centered on keeping each section contained so there was no spillover, Lyons explains. "Each type of material required its own formliners, so we had to carefully match sections and ensure each remained separate during casting," he says. "Some of the aspects to it became very complex."

Many of the panels are load-bearing, creating "wallumns," or a combination of walls and columns, in Shockey's parlance. "They were able to shave a little of the wall thickness down by combining the functions," Plank explains. "That helped provide more openness and flexibility on the interior.

Delivering and erecting the components also offered challenges. The woodgrain panels feature three or four vertical "fingers" that project to allow connections to be made. Those projections precluded the panels from being shipped flat due to the stress on their cross-sections. Shockey contracted with a Richmond, Va., hauler to load eight or nine of the panels vertically onto double-drops that were placed on low-boy trailers to protect the panels while providing the proper clearances.

Upon arrival, the panels were picked from the truck in the position in which they were being placed on the frame. Other components, including the 207,000 square feet of double tees and the stair and elevator panels, were delivered on traditional trucks and staged at a nearby location for erection as needed.

The panels had cast-in-place plates embedded into them, and they were connected to the foundation using splice sleeves, rather than setting the panels onto the plates. "The goal was to allow the stacked panels to act as one unit," Lyons explains. In part, this was done because the crane was limited in its maneuverability, requiring it to swing over two bays to locate some panels. The crane was placed in an outer bay and performed the erection from that spot.

"The general contractor did an excellent job with staging the area and providing access for a difficult process," Lyons says. "We had a steady stream of trucks going into the site and coming back out quickly. It all went fairly smoothly."

The finished parking structure blends beautifully and seamlessly with the architecture of the adjacent hospital and other buildings. The structure connects to the hospital, with a dropoff point at the front that leads to the hospital lobby and directs drivers around to the parking entrance.

"The owner was very pleased that all of the finishes on the hospital could be applied to a precast concrete structure," Plank says. "It creates a light, open look that enhances the patient experience as they arrive and depart."

Lyons agrees. "Everyone was very pleased with the results. We did a lot of things they thought couldn't be done. We're very proud of the work, because it looks beautiful. While I can't say this was the easiest project Shockey has ever completed, I'm glad to be able to say we could handle the complexity and challenges beyond even our own expectations."

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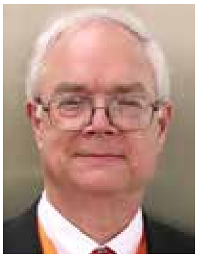
High-Performance Parking Structures Using Precast/Prestressed Concrete

— Ned Cleland, Ph.D., P.E.

More structures today are being challenged to be high performance, but what does this mean for a parking structure? High-performance structures are those that integrate and optimize all relevant attributes on a life-cycle basis. Therefore, designers and owners must consider what the relevant attributes are for a parking structure. Some of these include optimizing the layout and traffic flow for the site; meeting program requirements, such as efficiently providing the number of spaces needed; operational efficiency; providing a safe and secure environment for users; creating a durable structure to meet its intended service life, and reducing life-cycle costs, which includes energy use and maintenance.

However other relevant attributes might include meeting an aesthetic requirement; incorporating a mixed-use function, or being resilient enough to resist hurricane winds. Whatever the combination, it's important to integrate quality materials, design, and detailing to meet the demanding requirements of these facilities. Designers must also understand the advances in design methodology and practice to best achieve project goals.



– Ned Cleland is president of Blue Ridge Design Inc. and has more than 40 years of experience in structural analysis, design, research, and engineering management. He is nationally recognized for his expertise in precast/prestressed concrete and has designed or directed the design of nearly 300 parking structures. Dr. Cleland serves as chairman of both PCI's Parking Structures Committee and Technical Activities Council. He is also active in the American Concrete Institute (ACI) serving on several committees including ACI 318, 362, 550, and 374.

In the United States, the use of precast/prestressed concrete systems has been a favored method for parking structure construction for several decades. Throughout the years, there have been significant advances in techniques, technology, and details to make these structures more efficient, serviceable, and highly durable. Some of these advancements include new double tee widths up to 16-feet reducing the number of joints, increase in structural depth of stems to increase stiffness and reduce transient vibrations, and dry system connections and detailing so that use of cast-in-place concrete above the foundation can be limited to small transitions between sloped floors and pedestrian entrances. Overall, the strength, durability, resiliency, and sustainability of precast concrete have evolved to extraordinary levels. This article provides some guidance for system layouts and details to help designers achieve high-performance parking structures. More information can be found at http://www.pci.org/Project_Resources/Parking_Structures/.

'The strength, durability, resiliency, and sustainability of precast concrete have evolved to extraordinary levels.'

Framing Basics

Precast/prestressed concrete with long-span double tees is modular construction. Double tees are made in forms with standard widths with an allowance for joints. Typically precast concrete double-tee widths are 10 ft., 12 ft., 13 ft.-4 in., 15 ft., and 16 ft. Today, 12 ft. is the most common, but producers in various markets may offer a variety of double-tee widths. Framing layouts should be designed based on the double tee width, or module being used. For example when using a 12-ft double tee, a 48-ft. bay could be used. Narrow double tees can be made to fit spaces that are off-module because of functional features and constraints, such as stairwells, parking modules, and site limits.

Changes in framing must occur at the joints between the double tees. Ramps should start and stop at joints and at the end of beams. When needed for ramp slope and length limits, a small offset of the double tee joints can be made from the column centerline at the ends of ramps, but offsets greater than the width of the column will require a transition completed with cast-in-situ topping.

Ramps that provide the vertical circulation between levels are an essential feature of most parking garages. Unless exterior site grades provide direct access to upper levels, all parking structures must include ramps. The most efficient ramps are sloped full width bays that also accommodate parking. The slopes of the "park-on" ramps are limited to 1:15 (6.66%) by the International Building Code, but these ramps are commonly framed with 6% slope or less for higher levels of comfort and improved sight lines. Interior framing lines supporting ramps are framed more efficiently with walls than with back-to-back beams and columns. These walls can support the different framing levels on each side with less thickness and fewer components. It is common to provide module-spaced openings in these walls for ventilation, light, and security. The openings allow drivers and pedestrians better site lines, and reduced weight, reducing shipping costs.

Figure 1 shows part of the framing for a parking garage with modular bays and three long span bays with interior ramping. Other features of the high-performance details in this layout are drainage, joints and flange connections, and structural system design.

Drainage

Drainage of water from a structure is an essential part of designing a high-performance precast/prestressed concrete parking structure. Drainage requires attention to the global layout as well as to the local details. Water needs to be directed by slopes in two directions to the point where the drain is placed. On continuous ramp parking structures, the drains and drain lines typically are kept on the interior column lines to minimize the architectural impact of the vertical drain line on the exterior. This also minimizes the cost of the drainage system.

It is important to consider that prestressed double tees have a natural camber due to the prestressing. This causes the middle of the span to be higher than the ends. The amount of camber depends on the double tee section, the span, the loads, and the strength of the concrete, but typical applications should plan for camber between one and two inches. Basic guidelines can be found in ACI 362.1R-12, *"Guide for the Design and Construction of Durable Concrete Parking Structures."*[1] For pretopped double tees, the design slope parallel to the double tee should be 1½% percent, and the transverse slope should be 1%. For a typical 48 ft. bay with 60 ft. long double tees, this would slope the double tees 11 inches from outside to inside beam, and then 6 in. for the beam to the low end at the drain. Some double tees having less camber may permit less longitudinal slope, but the total slope from high corner to low corner should not be less than 1½% percent overall, which would result in 14 inches for a 48-ft. bay. A corner bay with these variations form the high corner elevation at 0" is shown in Figure 2. This pattern is repeated along the length of the garage in the "level," or nonsloping bays so there is a drain in every other bay.

For this layout in Figure 2, the slope on the outside supports, which are walls in this example, is the same as the slope of the inverted tee beam at the low end of the bay. Hence, this configuration avoids warping or twisting the floor.

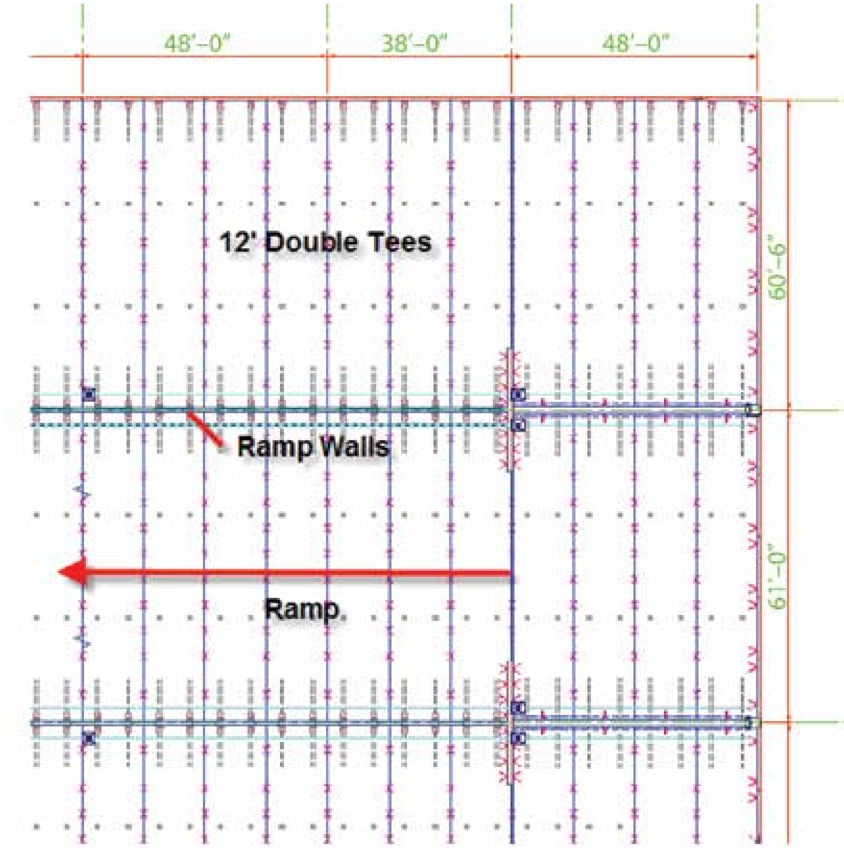


Figure 1 Common Framing Features.

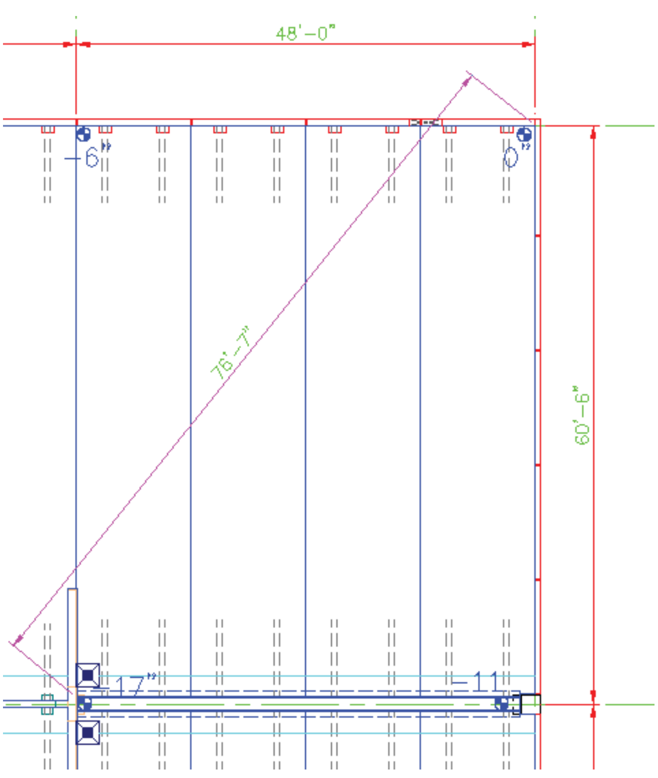


Figure 2 Slopes to Drain.

When spandrel beams are used for the exterior framing, they must be sufficiently deep to cover the depth of the double tees and the slope without the bottom of the double-tee stems showing below the beam. Slope can be developed in several ways such as:

1. The spandrel beam itself can slope,
2. The ledge within the spandrel

beam can be sloped, or

3. The dapped ends (blocked out sections) on the double tee stems can be variable to achieve the required slope.
4. For spandrel beams with corbel bearings, the corbels can be placed to provide the slope.

Twisting or warping the precast floor units is acceptable; provided they are sufficiently flexible and any transverse bending stress can be accommodated without cracking the flanges. Warping effects have been studied and reported in PCI papers.[2,3] Warping stress at the ends of the double tees is primarily an effect of transverse bending in the flange. The level of stress depends on the double-tee span, the amount of twisting, the stiffness and spacing of the stems, and the stiffness of the flange. These factors vary with the project layout and with the double-tee cross section, but in general 1 to 1½% of warping can be accommodated for pretopped members that span over 50 feet.

When the high ends of the double tees are held level, it is even more important to provide sufficient slope over the length. The floor parallel to the end spandrel beam should never be held level with the high ends of the tees. This configuration will result in ponding in the high corner because camber will prevent this configuration from draining

One particular type of parking structure design can cause difficulties in this regard. In a three-bay layout with a ramp in the center bay, it is difficult to achieve the recommended drainage slopes without unbalanced slopes across the garage. The outside bays slope to the inside beam lines at the ends of the ramp, so the elevations at each end of the interior double tees are the same. The slope along the beam will bring water toward the drains, but the camber of the double tees is often not sufficient for effective drainage. This can be addressed by providing a drainage "diamond" at the bottom of the ramp so that water follows the cross slope to the drain, shown in Figure 3. Note: drainage diamonds are typically only used with field-topped, double-tee applications.

After the drainage system is established, it is important to provide the local details to ensure that the system works. At the low end of the double tees, there needs to be a low line to collect water and direct it

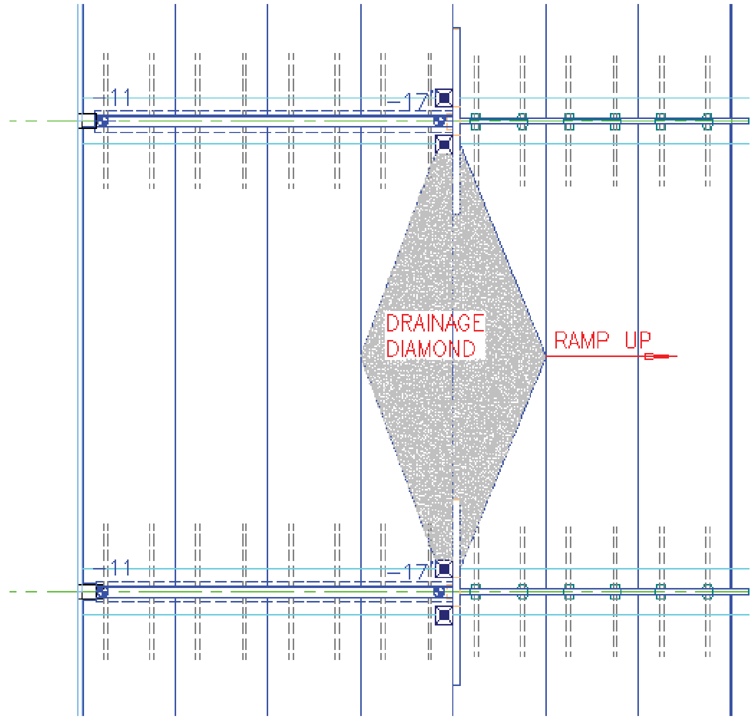


Figure 3 Drainage Diamond at Interior Base of Ramp.

to the drain. It is best that water not be directed across the sealed joints between the double tees and the inverted tee beam, so drains should be placed on either side of the beam. Figure 4 shows a layout with wash lines set to coincide with the centers of the drains. The ends of the double tees are made 2 inches higher than at the wash lines. When the system uses cast-in-place pour strips, the wash lines define the edge of the precast concrete pour strips. When the drains occur adjacent to a shear wall, as shown in this plan, it is necessary to provide openings for the water to pass though the wall to reach the drains.

When the precast double tees are cast with a wash and no pour strip is used, the drains can be cast into the flange. A section through a beam at an interior column illustrates this particular detail, in Figure 5. Specification-compliant drains for parking structures are commonly made in four parts. The iron casting for the rim is separate from the body of the drain that holds the strainer and has the pipe outlet. There are drains made with low rim profile (2 to 2½") that are suitable to be cast in the flange. After the rim is cast in, the drain body is mounted to the rim with a rubber gasket to seal the joint. The strainer and drain grate are then added to complete the drain. The double tee can be shipped to the site with the drain already set so that only the drain piping is needed. When the drains are set on the beam side of a shear wall at a cross-over bay, the walls also need openings below the drains for the piping to reach the drain leader piping that is usually placed on the inside corner for protection.

It is also important for headroom and piping efficiency to provide the drainage at the grade level in the same pattern used for the precast framing. The slab-on-ground needs to have similar variations in elevation to keep the same floor to floor heights.

Joints and Flange Connections

Parking structures are often subjected to severe and harsh environments. As with all precast concrete systems, the jointing and the connections define the behavior and performance, and therefore it is important to pay close attention to the details at joints, particularly in the flange-to-flange connections. Things such as weather, deicing salts, traffic loads, seismic strength, and ductility loads are more demanding on these types of joints than any other type of structure. The challenge can be met with attention to detail in design and construction, and the use of high-quality joint material.

Even when the parking garage is constructed with field-placed composite topping, the treatment of

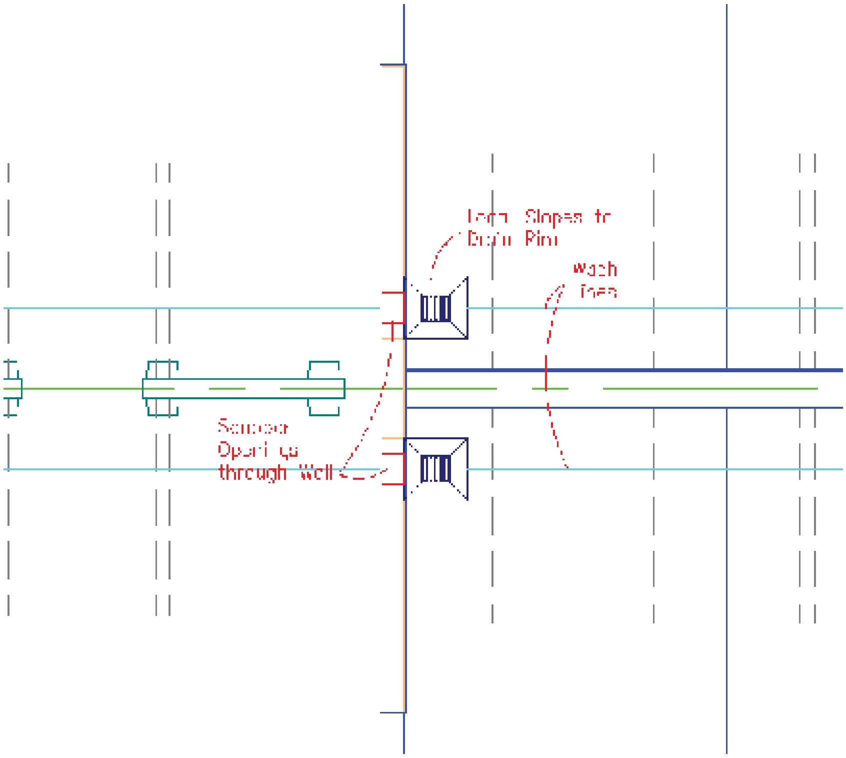


Figure 4 Local Plan at Interior Drains.

joints is critical. Wherever topping concrete crosses a joint in the underlying precast, there must be a tooled joint to provide control joints and a seam for waterproofing. Joints in the precast are natural locations for shrinkage and creep volume change movements to find relief. Tooled joints in a topping slab provide for movement to avoid irregular cracking in the topping, as well as provide a more resilient edge that can take the repetitive loading of traffic.

Experience has shown that movement in precast concrete systems is the sum of the small local movements that occur at joints. Lateral forces as well as volume changes (creep, shrinkage and temperature changes) put demands on flange connections and reinforcing. Temperature changes alone can create strain demands in the reinforcement that crosses these joints. For example, a welded wire reinforcement, with 10-inch-wide cross wire spacing, placed in the topping across joints might yield under movement caused from temperature change. Smaller diameter deformed bars may be a better solution for topping reinforcing as this type of reinforcement allows the joint opening strain to be distributed over the development length of the bars.

High-performance double tees in pretopped parking structures have the top edge of the flanges consolidated and shaped by tooling. Flange connections are spaced to provide for alignment of the flange surfaces, for continuity under moving traffic loads, and for shear transfer under lateral forces. These are typically spaced 4 to 5 ft. in the drive lanes, with wider spaces in the parking spaces and near the ends of the double tees. These connections are subject to transient loading and must be detailed for durability and fatigue. These connections must have the capability to flex without damaging the concrete that holds them. There are three essential points for connection performance.

1. The material for the connections should meet the recommendations of ACI 362.1R-12 for the exposure zone of the project. For the most aggressive environmental conditions, stainless steel is the recommended connection material.
2. These connections should not be over-welded. The strength of the connections is developed with welds that are about one half the length of the exposed weld surface. Limiting the weld to the center of this interface keeps the flexibility that is needed for the connection to tolerate traffic and volume change movements without damaging the underlying concrete.
3. The edges of the embedded part must be isolated from confining concrete so that the flexing of the parts does not cause a spall on the top, sides or bottom of the flange.

Figure 6 shows flange connection

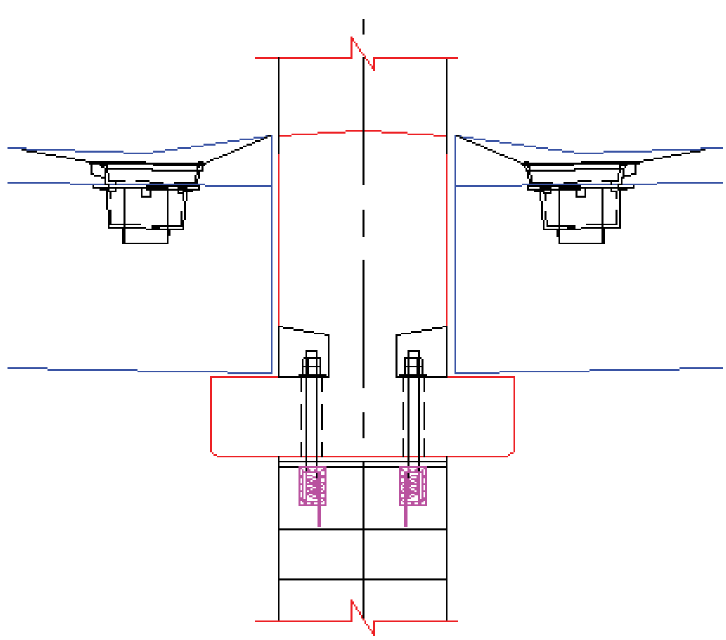


Figure 5 Drains Cast in Precast Wash.

details used with pretopped double tees with ¾" recess from the top surface. This detail also shows isolation to remove concrete immediately below the embedded part so that it is free to deflect without prying the edge of the flange that can cause a spall. There are variations on commercial and plant-fabricated parts that can meet the high demands of this application, but each needs to be installed to meet these three essential points.

The double tee also has chord connections at the ends to take the tension and compression of the floor acting as a diaphragm. In a system using pour strips, the chord reinforcing is mild steel placed in the cast-in-place concrete topping. Attention to durability in the pour strips is important. The cast-in-place concrete should be at least 5,000 psi concrete with air entrainment and a water/cementitious material ratio not greater than 0.40. Adding corrosion inhibitor or using epoxy-coated reinforcing as additional protection in higher exposure zones may also be needed. It is important that the field crews placing this concrete understand the final shape of the pour strip washes must positively direct water to the drains.

When the chord connectors are designed for the dry system, they should follow the same principles applied to flange connections. These connections usually link continuous bars that cross the ends of the double-tee flanges. A low-profile detail using vertical or slightly tilted plates with a slug weld link is shown in Figure 7. As these connections are placed at the ends of the double tees, they are subject to less movement, and are more rigid than typical flange connectors. These connections should also have some isolation around the face plates to accommodate movement, including expansion during welding. Concrete below the face plates is also subject to damage of this type.

The double tees are also connected across joints at the ends to beams, spandrel beams, or walls. When possible, it is best to locate these connections on the underside of the flange so that it is isolated from the exposure of the top surface and well below the sealed joint.

Completion of the joints requires proper placement of a high-quality joint sealant by a qualified installer. One-part or multipart urethane sealant is most commonly used in high-performance precast parking structures. These materials must be installed with proper joint preparation, which includes the use of a compatible primer for most installations. Tooled joints make this installation easier, but any irregularities or tight joints should be ground to provide a uniform substrate without soft edges or laitance. The sealant shape should be maintained using a backer rod placed at the proper depth below the floor line. Where the sealant crosses connections, it is important to use a bond-breaker over the link so the seal can move with the remaining parts of the joint. In areas of high exposure, such as open roofs, silicone sealers are sometimes used for longer effective life.

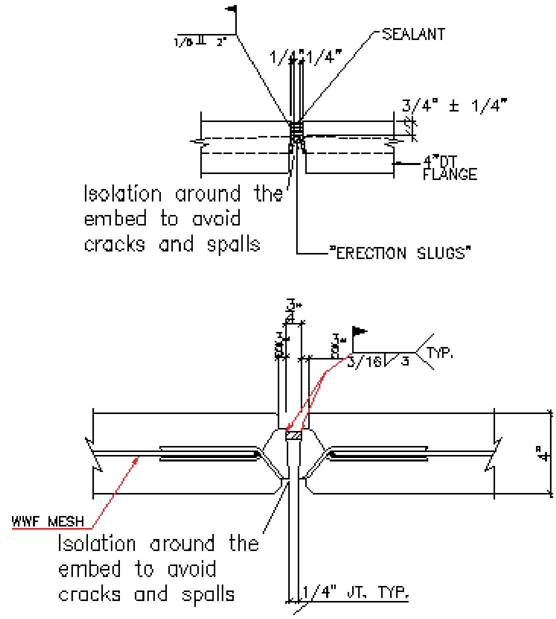


Figure 6 Flange Connection Details.

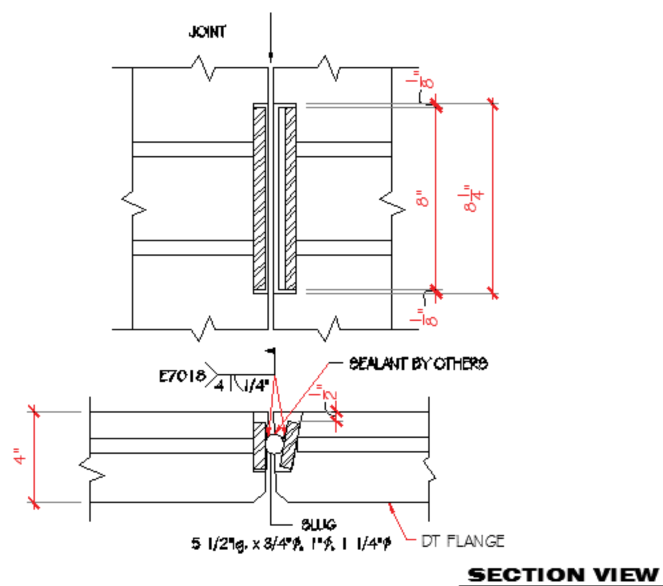


Figure 7 Dry System Chord Connector.

Structural System Design

After considering the basic framing guidelines as well as the drainage and joint details, the designer must assure that the overall structural system layout meets the needs due to gravity, lateral, and volume change forces. The strength and stiffness of the structure is required to resist wind and earthquake loads. The structural system performs best with simple and symmetric lateral force-resisting elements such as shear walls which are favored due to their strength and economy. In many high-performance structures, ramp walls provide the dual function of resisting gravity and lateral loads.

Sight lines when using shear walls can be improved by limiting the wall lengths to only what is necessary, and by casting in wall openings as long as the remaining portion of the wall can transfer the required loads. The typical framing layout shown in Figure 1 uses shear walls instead of columns at the ends of the ramp. If the wall obstruction at a cross-over bay is too great, these transverse shear walls can be located further into the structure away from the end of the ramp. These transverse shear walls can also be connected to the ramp walls forming a cruciform shape and benefitting from the resistance to overturn due to the dead load from the ramp walls.

The structural system must be configured to accommodate volume changes. Location, orientation, and connections to the lateral force-resisting system should be considered to reduce restraint and allow the structure to respond to temperature movements. The *PCI Design Handbook*[4] provides guidance on the acceptable lengths of buildings without expansion joints. Well-configured framing with ductile connections can allow these limits to be stretched to eliminate the need for expansion joints, but the designer must take care not to create excessive movement in the joints that are provided. Because expansion joints create additional demands for seismic detailing, for gravity load transfer, and for attention to maintenance, when a layout is near the limits, it is usually best to leave expansion joints out.

Conclusion

Precast concrete is an outstanding material and system to build high-performance parking structures. Precast concrete is an inherently durable material that provides design and aesthetic versatility, accelerated construction, with a high degree of quality. However, careful attention to planning, detailing, and fabrication of the structure, along with the proper routine maintenance will lead to increased service life and reduced life cycle costs. Ultimately, all of these considerations help designers and owners build and operate high-performance parking structures.

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For more information on these or other projects, visit www.pci.org/ascent.

Four Keys to Long-Term Parking Structure Success

Design, materials, construction, and maintenance all must come together to ensure a resilient, aesthetically pleasing, and cost-effective parking structure over the long term

— Francesco J. Genoese and Rick Petricca

Many factors go into creating a successful parking structure for both the short and long term. While owners want to create an efficient and durable structure, the definitions of these terms continue to evolve, especially with advancements in design and material technologies. This article summarizes significant aspects of parking structure design and maintenance, and also highlights important aspects that may be overlooked or misunderstood. It can also be used as a checklist to aid in any phase of parking structure design, construction, and ownership.

The four key areas of concentration—design, materials, construction, and maintenance—represent the areas of discipline involved in the life of a parking structure. You can find PCI technical resources related to the parking structure topics covered in this article: www.pci.org/Project_Resources/Parking_Structures/.

Design Techniques

All precast concrete structures are designed with "breathable" connections that allow for movement from ordinary thermal expansion and contraction. This basic design practice reduces potential cracking and thus maintenance costs.

Precast concrete parking structures are designed to meet codes, but consideration must be made to ensure members are not overdesigned to the point that they cause tensile stress. Live loads, snow loads, and snow drift loads can be combined and reduced to better represent the realistic loads and behavior of each structure. Good design will reduce the potential for cracking and thus reduce any potential deterioration from water or chlorides. Other systems typically experience random and unpredictable cracking that leads to more extensive repair costs.

Drainage is a key part of any parking-structure design. Proper drainage details and a positive slope of a minimum of 1.5% are essential to prevent water saturation and ponding. Good design also includes sizing and location of drains, properly set elevations of landings and high points, and slope creation to shed water to low areas while maintaining clearance.

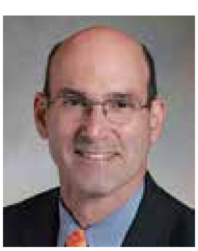
Specific design of precast structures will vary based where the structure is geographically located. Just like design, maintenance programs will have specific plans based on the environment the garage is in. The common denominator of precast is that with good design and properly prescribed and executed maintenance, life-cycle costs are minimized, consistent and predictable. Every precast producer plays a key role in helping customize a maintenance program for the garage they provide to assure that their structure has the lowest life-cycle cost of any system.

You can learn more about design specifics in the article titled *"High-Performance Parking Structures Using Precast/Prestressed Concrete,"* also in this issue of *Ascent*.

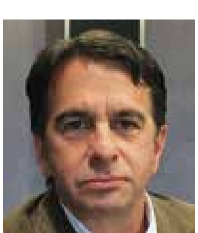
Material Selections

The manufacturing process of precast concrete inherently results in a very high-quality, high-performance concrete, ensuring the longevity of the structure beyond any other system. Factory-controlled and -cured concrete with a low water/cement ratio containing corrosion-inhibiting admixtures, fly ash, or silica fume are proven to increase durability. This concrete, typically combined with stainless-steel welded connections and hot-dipped, galvanized exposed embed plates, resists chloride ion penetration and corrosion. It is also common practice for Silane sealer to be spray applied to all horizontal surfaces of precast parking structures for added protection in climates where deicing materials are used. Field installed concrete topping and infills should always be treated with Silane sealer in such climates.

Contributing Experts



– Francesco J. Genoese is the senior director of StructureCare consulting services at High Concrete Group in Denver, Pa.



– Rick Petricca is vice president at Unistress Corp. in Pittsfield, Mass.

High-Performance Precast Parking Structures

Precast concrete components provide significant versatility, allowing them to be used to meet all types of aesthetic needs. This ensures that designers can be confident that any aesthetic requirement can be met while specifying the material for its other key advantages. Some of the potential benefits include:

- long spans and open floor plans;
- a compressed construction schedule due to off-site fabrication;
- high quality control of the fabrication processes, governed by certified-plant requirements;
- consistent, fast, high-quality erection processes, governed by certified field programs; and
- high strength and long-term durability due to the use of specialized, high-performance materials.

As a manufactured and engineered product, precast concrete can be fine-tuned to meet each project's specific needs. Its capabilities continue to expand as new techniques and procedures are developed to advance its properties. For example, some of the structural connections used to attach the various components during the installation process utilize stainless-steel hardware today. Where "durable" once meant a 50-year service life, material designs and maintenance programs are combining to offer the potential for a 100-year service life when desired.

Members of the Precast/Prestressed Concrete Institute discuss and evaluate the advances in material science on a regular basis and provide insight to help create a manual defining "Recommended Practices" for parking structures. Following prescribed garage practices will result in good use of space, flexibility, maintainability, reduced construction time, reduced life-cycle costs, and ultimately a better value for any project.

The 3rd Edition of "Parking Structures: Recommended Practice for Design & Construction" will be available in 2015.

Braced precast concrete wall panel during erection.

Precast Concrete double tee being installed.

Construction Techniques

Parking structures are constructed using one of several common structural systems. These include cast-in-place concrete using either conventional or post-tensioned reinforcement, prestressed/precast concrete, or hybrid systems featuring a combination of these systems and sometimes steel. While the systems have some features in common, each has specific attributes that impact construction speed, cost, aesthetics, function, durability, and long-term maintenance. As noted at the beginning, prestressed/precast concrete offers several unique benefits.

Parking structures featuring prefabricated components are assembled like an Erector® Set. The installation process involves hoisting individual components into position and using welded, grouted, and bolted connections to join them together. These connections are often concealed within the component joints and protected with joint sealants. Plant-cast or cast-in-place concrete pour strips, usually located around the garage perimeter and at pedestrian access areas, conceal reinforcing steel and connections. They also provide drainage and pedestrian transitions.

All parking structures have common elements including directional signage and line striping, lighting, drainage systems, stairways/elevators, height-restriction warning devices, and weight limits. All of these systems and features have specific needs and requirements for proper operation and service life.

Unlike enclosed buildings, parking structures are directly exposed to weather, traffic, and other environmental conditions. A variety of influences impact the durability of these structures in ways other buildings are not. These include extreme temperature changes, rain, snow, deicing chemicals, ultraviolet light, road grime, oversized vehicles, cyclic vehicular loading, and potentially abusive maintenance, like snow plowing.

Even with their inherent high durability, precast concrete parking structures (as with all such structures) require preventive and proactive maintenance to ensure long service life. Preventive maintenance should be planned and performed at regular intervals, much as with routine maintenance on a car, to minimize long-term operational costs relating to maintenance and repair and to ensure uninterrupted service.

Maintenance in parking structures is usually categorized into three key areas: housekeeping, preventive maintenance, and repairs and replacements. Housekeeping involves routine and periodic tasks meant to keep the garage clean and functioning efficiently. It typically includes tasks like lamp replacement, line striping and signage maintenance, and parking-control and security-system maintenance.

The long-term integrity of a parking structure is particularly dependent on the last two categories. Preventive maintenance usually involves longer-term maintenance intended to control deterioration, ensure safety, and maintain key systems. Repairs and replacements are required to address premature deterioration or damage and to restore systems at the end of

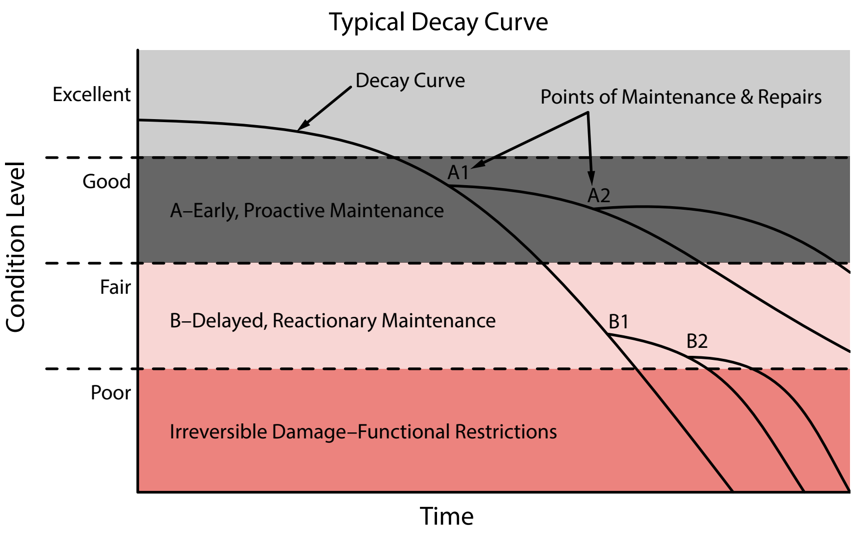


Figure: High Concrete Group LLC–StructureCare.

Stainless weld connections and proper precast joint alignment.

their service life. In precast concrete parking structures, these typically include waterproofing systems, cast-in-place concrete interfaces, and more serious damage and deterioration.

Preventive Maintenance Program

A well-developed preventive-maintenance program should start as soon as a garage is placed into service, while it is in its best condition. Early and frequent preventive-maintenance activities will maximize gains to the service life relative to the dollars spent. Delayed, reactionary maintenance provides only short-term gains that require larger expenditures at more frequent intervals. Lack of a preventive-maintenance program also can result in untimely service interruptions and unsightly and unsafe conditions.

The components of a preventive-maintenance program need to be specific to the garage and its operating conditions. For example, parking structures in colder climates have more stringent requirements due to the effects of winter. The colder temperatures and maintenance needs required to deal with ice and snow dictate a plan to remove harmful deicing chemicals from the deck surfaces in the spring time to prevent corrosion and possible moisture penetration. These regions also need a plan that deals with a review of equipment, weight restrictions, and how to avoid damage to sensitive areas.

In other regions, such conditions as sun exposure, seismic activity, and marine exposure may dictate a different approach to the maintenance plan. For example, in coastal environments, more frequent deck wash-downs will help reduce the exposure to harmful chlorides.

Regardless of location, the fundamental elements of an effective preventive-maintenance program include periodic inspections, structural audits, leak surveys, periodic maintenance training, and routine repairs and maintenance to key systems guided by the inspection process and diagnostic testing.

Annual Assessment Needed

Once the plan is developed, a re-evaluation of all components should occur every three to five years. Experience is important in this process. Periodic informal safety audits and routine weekly and monthly inspections can be completed by operations staff with some training. Annual assessments of the structural elements and protective systems in the garage, however, should be completed by a professional experienced with garage design, construction, and repair. The operations staff and the hired consultant together form the maintenance team.

These annual assessments can be informal and representative, depending on the age and condition of the garage. However, a formal, comprehensive structural audit should be completed with documented results at least once every five years. In addition to fully documenting the various observations, any developing conditions and symptoms should be evaluated for root cause. These will guide long-term repair recommendations that will help the operator/owner develop a maintenance and repair program to plan and schedule future repairs and maintenance.

Typical Multiyear Service Outline
Summary and Interval of Services

Service	Year 1	Year 2	Year 3	Year 4	Year 5
Formal Assessment Structural Audit					X
Informal Assessment	X	X	X	X	
Walk-Through Monitoring–Periodic	X	X	X	X	X
Leak Survey	X	X	X	X	X
Reporting	Informal	Informal	Informal	Informal	Formal
Deicing Wash-Down (Winter Regions)	X	X	X	X	X
Misc. Repairs and Maintenance	X	X	X	X	X
On-Site Maintenance Support & Training	X	X	X	X	X
Snow-Ice Removal Training (Winter Regions)	X	X	X	X	X

Table: High Concrete Group LLC–StructureCare.

Annual leak surveys, particularly focused on areas just below the roof level, can help identify sealant failures at an early stage. This will allow smaller, selective repairs while the sealants are still repairable and avoid them contributing to a larger problem. These selective repairs can extend the overall service life of the waterproofing systems, which can include sealants, expansion joints, and membrane coatings.

Maintenance training can help the operations staff understand what to look for and how to implement their periodic inspection program. In colder environments, annual training should include winter maintenance. Diagnostic testing may assist professionals in assessing the underlying conditions and in developing recommendations for future maintenance and repair.

A well-developed preventive-maintenance program will go a long way in mitigating operations cost and extending the service life of a parking structure. It will also slow down the deterioration process. Eventually, however, repairs and replacements will be required. Root cause-based repairs should be directed by a knowledgeable professional. These repairs often involve waterproofing systems and localized concrete deterioration. Corrosion in miscellaneous hardware and railings also may need to be addressed.

Replacement of these components involves system upgrades typically relating to service-life failures. In precast concrete parking structures, these replacements usually do not involve the precast concrete components, due to their inherent durability and quality. Instead, they focus on waterproofing systems, such as joint sealants, expansion joints and membrane coatings, drainage systems, line striping, signage, lighting, and the cast-in-place concrete elements.

Systems Need Review

While parking structures are designed for service lives of 50 years or more, the systems on which they rely have a much shorter service life. For example, roof-level urethane sealants, which are typically used in garages, can last eight to 10 years due to winter-maintenance activities and ultraviolet-light exposure. These same sealants on lower levels can last 12 to 15 years. Expansion joints, depending on the joint type, can last from eight to 15 years. Drainage systems typically last 12 to 15 years, but can last longer. As a result, selective replacements will be necessary over the service life of the structure.

It's important to note that the annual inspection component of the preventive-maintenance program can help prolong the service life of these systems by identifying developing deterioration and damage early on, allowing for small and less costly repairs.

As is often the case, long-term neglect or misguided maintenance and repairs often precipitate premature failure in parking structures. The deterioration progression accelerates as conditions worsen. In these instances, simple repairs are no longer viable options. Full-scale restoration is required, which should be guided by a professional experienced in design and restoration.

If it hasn't already been completed, a thorough structural evaluation is often needed to help assess and devise appropriate repair strategies. In addition to addressing structural needs, consideration must include operational logistics, cost, and a feasible implementation time schedule. An experienced consultant can be invaluable in this process.

Positive drainage design, proper drain locations utilizing precast washes.

Parking Garages
Maintenance–Inspection Checklist

#	Inspection/Maintenance Task	D	W	M	S	A	Comments
1	Parking and Drive Aisle Debris/Trash	X					
2	Stair Tower Debris/Trash	X					
3	Elevator Debris/Trash	X					
4	Graffiti–Vandalism			X			
5	Oil Accumulation/Staining			X			Slippery Conditions at Parking Stalls
6	Floor Drains–Inspect/Clean Grates		X				
7	Ponding Conditions	X					Squeegee Water as Needed
8	Signage–Visibility, Lighting, Cleaning			X			
9	Striping–Visibility & Fading				X		Include Curbs and Directional Symbols
10	Lighting–Relamping Needs		X				
11	Lighting–Fixture Cleaning			X			
12	Lighting–Timers				X		
13	Tripping Hazards	X					
14	Slippery Conditions–Pedestrian Areas	X					Particularly Duing Wet and/or Cold Weather
15	General Safety Concerns	X					
16	Winter Maintenance Review/Training					X	Consultant Lead
17	Snow–Ice Management	X					Seasonal
18	Doors & Door Hardware		X	X			Inspect for Operation (W) and Corrosion (M)
19	Concrete Debris	X					Identify Location and Contact Consultant
20	Obvious Leaking Conditions	X					Identify Location and Contact Consultant
21	Rusting Conditions			X			
22	Concrete Deterioration			X			Identify Location and Contact Consultant
23	Deicing Removal–Deck Wash Down					X	Spring Time After Last Freeze
24	Guard Rails, Stair Rails, Cable Barriers			X			
25	Oil Stains on Underside of Floors			X			Identify Location and Contact Consultant
26	Roofing/Flashing					X	Most Likely Assigned to a Roofing Vendor
27	Ventilation Equipment			X			Stair/Elevator Towers & Parking Areas
28	Water Supply–Leak Survey			X			
29	Water Supply–Drain/Blowout					X	
30	Exterior Masonry/Concrete Inspection			X			Scan for Signs of Deterioration
31	Floor & Stair Tower Leak Survey					X	Focus on Roof Level
32	Membrane Coatings			X			Inspect and Keep Clean
33	Expansion Joints			X			Inspect for Damage, Particularly During Winter

Table: High Concrete Group LLC–StructureCare.

A common mistake made by many facility managers is to ignore or minimize preventive maintenance and ongoing repair programs following major restoration. The new appearance and considerable financial outlay provide a false sense of accomplishment and security. Unfortunately, this type of major restoration usually occurs late in the life cycle of the structure, providing a short-lived extension of service life, particularly in the absence of proactive maintenance. Now more than ever, a proactive and well-developed maintenance program is essential. Re-evaluation of this program is particularly important following major restoration.

To help with the implementation of the maintenance program, it's helpful to develop an annual implementation schedule and checklists to guide the effort. The following table can be used to outline the components and timing of various tasks.

The following inspection checklist is an example of the type of document that can be used for operations and professional staff.

In summary, an effective parking garage maintenance program should follow five key points:

1. Be proactive and sustained.
2. Identify and address deterioration and damage early.
3. Be guided by experienced eyes—engage a parking structure professional.
4. Be based on root-cause assessment and solutions.
5. Be re-evaluated every three to five years and after major repairs and restoration.

Precast concrete parking structures are the most durable, fastest to construct, and most cost-effective designs possible, offering service lives that can reach 100 years. But their durability should not lead owners and designers to consider them to be impervious. Routine, regular maintenance will ensure no weak links develop that can result in long-term and costly problems down the road. A small amount of time, money, and effort spent at regular intervals will ensure the parking structure continues to be attractive and fully functional throughout its life.

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Precast's Versatility Expands Use of Terra-Cotta

High-Performance precast helps to fuel the resurgence in the use of terra-cotta

— Craig A. Shutt

Terra-cotta tiles have been used to clad buildings in the United States for several decades, providing a distinctive aesthetic touch. Today, designers are discovering they can embed terra-cotta into architectural and structural precast concrete panels as a means to more efficiently use terra-cotta on projects. There are also several additional benefits, including aesthetic versatility, accelerated construction, reducing the number of joints and maintenance costs, and high thermal performance.

'Terra-cotta is an old material being used in a new way.'

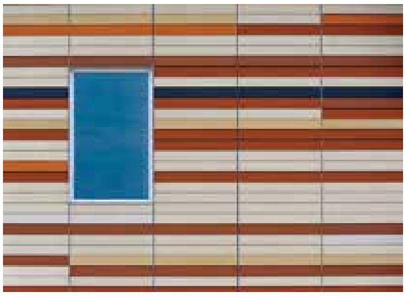
"Terra-cotta is an old material being used in a new way," says Kristen Vican, associate vice president at RTKL Associates in Washington, D.C. The architectural firm has used terra-cotta with rainscreens on a number of projects, especially abroad. But hand-setting the material into the rainscreen is cheaper overseas. "It's not as economical to hand-set it here, so it's difficult to work it into the budget. We like the material, but needed to find an economical way to feature it."

"There's a lot of interest in terra-cotta right now," says Dirk McClure, regional director of sales and business development at Enterprise Precast Concrete Inc. in Overland Park, Kan. His company has produced some projects using terra-cotta. "It's a traditional masonry material that can be used in a contemporary way."

"The benefits of the material make it popular," explains Bud Streff, director of sales for NBK North America, a German-based supplier of terra-cotta. "It has been used for 15 years in major markets, and now it's expanding into all parts of the country and all types of buildings. Designers realize that it has great color retention, so it creates a desirable look." Adds Vican, "It's a modular material that offers longer, linear tiles than other options. We like it because it creates larger modules than brick can provide."

Rainscreen Alternatives

Its most common application has been in rainscreens, but that creates challenges. Those solutions lead



Terra-cotta was embedded into insulated precast concrete panels at the University of Missouri's Henry W. Bloch Executive Hall for Entrepreneurship and Innovation in Kansas City, Mo., when designers found it was more economical than cladding a rain-screen. Photos: Jacia Phillips Photography.

to higher material and labor costs. McClure says, "Rain can get behind a screen, so additional protection is needed to shield the wall. That means budget issues can arise with setting the terra-cotta and then protecting the building. Not only is it a very complicated detailing process, but a lot of the 'rainscreen to wall' connections are concealed. That can create issues if there are moisture or any other problems down the road."

Those were some of the challenges faced by designers with the University of Missouri's Henry W. Bloch Executive Hall for Entrepreneurship and Innovation in Kansas City, for which Enterprise fabricated insulated wall panels with embedded terra-cotta. "We wanted to use terra-cotta, and we started looking at rainscreens, but we needed to reduce the cost," explains Greg Sheldon, senior project architect and associate principal at BNIM, the architectural firm for the project. "We'd completed some terra-cotta projects and had a vast experience with casting clay-faced materials into precast concrete, so it seemed feasible."

Replacing rainscreens with precast concrete panels produces a more economical design because of precast concrete's ability to provide multiple functions, McClure says. "Precast concrete can stop moisture on the exterior wythe, which really simplifies detailing and reduces materials. It also consolidates trades and makes the entire process simpler."

'The cost of a terra-cotta precast concrete panel is more economical than a rainscreen design.'

NBK's Streff agrees. "The cost of a terra-cotta precast concrete panel is more economical than a rainscreen design, which requires stud backing, sheathing, membrane, and aluminum extrusions. It can achieve the same look, but provide a more cost-effective solution for your client."

The insulated wall panels on the Bloch Hall project also provided high thermal performance. Sheldon explains, "Our goal was to ensure the envelope would contribute to LEED requirements." An analysis of the building's enclosure showed the best approach to be two, 4-inch wythes of concrete sandwiched around 3 inches of rigid insulation. "Enterprise wanted the panels to have composite action so the panels would work together. We built the wall panels with the optimum insulation and thickness to handle the terra-cotta and provide thermal performance."

Incorporating terra-cotta into the precast concrete worked well. The project won the Harry H. Edwards Industry Advancement Award and the award for Best Higher Education Building in the 2014 PCI Design Awards competition (for details on the project, see the Fall 2014 issue of *Ascent*).

Insulated panels with embedded terra-cotta also were designed for the Salt Lake City Public Safety Building, where durability and safety protection were critical elements. The precast concrete panels consisted of an exterior wythe of 1$\frac{3}{16}$ inches of terra-cotta, which was embedded into a 3$\frac{3}{16}$ inches thick of concrete, creating a total wythe thickness of slightly more than 4 inches. The exterior terra-cotta embedded wythe and an interior 4-inch wythe of concrete sandwiched 2½ inches of rigid polyisocyanurate insulation to complete the building's enclosure.

"That thickness of stone and concrete provides a pretty good deterrent" to high-caliber ballistic penetration, explains Kevin Miller, president and principal in charge of the project at GSBS Architects. Tests showed no projectile could penetrate the second layer of concrete, much less go through it.

The 9-foot-tall by 30-foot-long panels were attached to steel columns so as to allow the panels to move with the frame. The panel sizes and weights created no special challenges in connecting them to the frame for the precaster, Hanson Structural Precast.

Structural Options

Terra-cotta panels have been used with standard, noninsulated architectural panels as well as structural panels. The first use of structural panels was at the Consolidated Rental Car Facility (CONRAC) at Logan International Airport in Boston, Mass. "We had seen this approach used in Germany, but we didn't know if it could work here," says Camille Bechara, project manager and lead designer with Parsons Brinckerhoff, the architectural and engineering firm on the project. "We worked through everything carefully."

That included tests for humidity, elasticity, movement between materials, and maintenance needs

The Consolidated Rental Car Facility (CONRAC) at Logan International Airport in Boston, Mass., features the first use of terra-cotta embedded into structural precast concrete panels. Photos: Fennick McCredie Architecture.

as they related to structural panels, he notes. "We had to identify the issues and test the impact of everything."

The initial plan, as with the Bloch Hall building, was to attach the terra-cotta to a rainscreen in front of traditional structural precast concrete panels. But the team realized that embedding the terra-cotta into the structural panels could save about $1 million in material and construction costs. Those panels, cast by Blakeslee Prestress in Branford, Conn., were 51 feet tall, 12 feet wide, and 10½ inches thick, with 2- by 3-foot, ¾-inch terra-cotta pieces set into the panels.

To ensure this first structural use would perform well, considerable testing was done to ensure no deflection, cracking, or maintenance issues would arise. Life-size mock-ups were even driven around the plant's grounds over bumpy roads to evaluate the impact of worst-case delivery conditions. Some tiles were deliberately cracked and repaired. "We wanted to see what the chances were for cracking and how easily panels could be repaired or replaced if needed," says Bechara. "The response to the tests really made this approach attractive."

Collaboration Is Key

Testing, along with full-size mock-ups, are critical at this early stage of experience, says Vican. She helped design the Hyatt Regency at Tysons Corner in McClean, Va., which features terra-cotta pieces embedded into precast concrete panels. The $70-million, 1.4-million-square-foot hotel expansion is designed to achieve LEED certification.

"Early collaboration is the key," she says. Discussions about design concepts and detailing concerns need to be addressed with the precaster and terra-cotta tile manufacturer, and the plants should be visited to understand the material and fabrication restraints. "Make sure your specifications include the testing and visual mock-up requirements."

Sheldon agrees. "Diligent research and engineering by the precaster

Terra-cotta was embedded into the precast concrete architectural walls used to clad the Hyatt Regency expansion at Tysons Corner in McClean, Va. A custom frame was designed to cover the edges of panels at window openings to avoid the necessity of returns on panels. Photos: RTKL Associates.

helped overcome potential production challenges related to the use of terra-cotta in an insulated panel," he says. "Everything was explored, from the coefficient of thermal expansion to the amount of precast bowing that the tiles could withstand before cracking, the optimal thickness of the tile, reaction of the panel during freeze-thaw cycles, and more." The precast was produced by Gate Precast in Oxford, N.C.

During production, it is important to review the panelization plan and details with the contractor and to review critical details, such as joints and face mixes in the mock-up stage, Vican notes. The precaster's plant should also be visited during the fabrication to view the work in progress.

Many Color Options

For the Bloch building, which included seven shades of terra-cotta and one glazed accent (comprising eight colors in all), designers created color-coded charts that outlined where each piece in each color of terra-cotta (all of which were the same 6-inch tall by 4-foot-long size) should be placed for each panel. "We used eight colors because each new color had a cost implication," says Sheldon. Their goal was to use the same colors throughout but overbalance the shades to make one side redder and another more buff to complement adjacent structures in those tones. "We tried to balance the colors so it all worked while 'talking' to nearby buildings."

The color-coded charts were more precise than typical embedded brick, Enterprises' McClure says. For those applications, architects typically provide the percentages of each color desired and the precaster lays them out in a random format. Due to the nuanced color changes from one façade to another, this was more precise. It's a seemingly random pattern, but there was actually nothing random about it, from the standpoint of our casting process."

Terra-cotta color options vary, as with other clay-faced products. That offers opportunities to create unique looks. Although the Bloch project used eight colors due to its unique goals, projects typically use one to three colors. NBK terra-cotta colors are made from different color recipes and firing techniques, Streff notes.

Three colors were used on the Public Safety Building in Salt Lake City, Utah. "We wanted a look that was refined, clean, and simple, but also one that spoke to the function of the building through its durability and strength," Miller explains. The terra-cotta tiles were fired as 1- by 5-foot pieces to create a 30-foot grid pattern. "The long, narrow dimensions were large enough to make panelization economical without requiring special connections or design considerations to provide the necessary seismic movement."

Dimensional Variations

Most projects have used terra-cotta tiles of a 25-mm thicknesses, as designers have found this thickness provides the optimum combination of stiffness and flexibility to work with the weight and thickness of the panels. NBK can make tiles in a range from 20 mm to 30 mm, Streff says. Adds Sheldon, "The panels can be pretty stiff and robust even at 20 mm."

Terra-cotta dimensional capabilities are more versatile than with standard bricks, one of the material's key attractions. But there also are limitations, with a need to balance height and length to achieve the best structural performance, Streff notes. The solid tiles used with precast concrete installations typically are no longer than 5 feet and between 6 inches and 2 feet in height.

Bloch Hall's 12-foot-wide panels couldn't use two 6-foot panels, so three 4-foot ones were specified. "The 4-foot length was comfortable and eliminated any concerns about flexure issues with longer pieces," Sheldon says.

Detailing Concerns

Possibly the biggest concern involves detailing, as the details and specifications have not existed until now, says Vican. It is critical that the floor-to-floor heights work with the tile dimensions to avoid having to cut the tile and leave an exposed edge. "Horizontal dimensions are more critical than vertical ones, since tiles can be more easily modified," she says. Punched windows also must be coordinated to ensure the tile joints align.

Terra-cotta tiles that were $1\,^{3}/_{16}$ inches thick were embedded into insulated precast concrete panels to clad the Public Safety Building in Salt Lake City, Utah. The high-performance precast concrete panels provided both energy efficiency and protection from ballistic penetration. Photos: Benjamin Lowry, GSBS Architects.

On the Hyatt Regency project, RTKL designers considered different window options, with punched windows preferred, she says. "They're harder to do with terra-cotta because of the need to cut the tile."

Terra-cotta Properties

- Clay-based product.
- Very dense, with low absorption (4-7%).
- Tiles are still wet before casting to prevent excessive absorption of water in curing process.
- Tight tolerances (1⁄16-inch) can be achieved.
- Extruded with grooves on back to aid bonding.
- Must meet ASTM requirements to qualify for facing, including:
  - Absorption.
  - Flexural Strength.
  - Weight.
  - Thermal Expansion.
  - Freeze-thaw.
  - Hardness.
  - Efflorescence.
  - Chemical Resistance.
  - Compressive Strength.
  - Glaze Resistance to Crazing & Freeze-Thaw.
  - Dimensional Tolerances.
  - Warping Tolerances.

To resolve this, the team created a custom mullion that covers the edges. The team investigated creating pieces with a return, but they required a two-stage pour that wasn't cost efficient.

"Most terra-cotta-faced precast concrete designs keep the windows to the exterior face to resolve issues," she notes. "The concern with creating metal frames and trim is that the design still needs to allow tolerances for each material, which creates a wider gap."

Vertical joints are the key concern, with a requirement that water cannot infiltrate behind the joints. Horizontal joints are less problematic because they typically are shiplapped. To ensure continuity of the terra-cotta between panels without changing the joint width, joints should be the governing factor and the width at the overlap should accommodate the tile lip, she notes.

Custom tiles with finished edges and no shiplap extension may be required between precast panels, and at the top and bottom of rough openings. Angled tiles should be used at sill conditions.

Full-size, mock-up panels are essential to ensure no surprises once the erection begins, Vican notes. An aesthetic review should include the location and color of face mixes, selection of reveal depths, and selection of sealant colors. A review of patch and repair procedures is also important, including the process for replacing a full tile and for repairing minor damage. Tests performed on the materials, at an independent facility, should include tests for tensile bond strength (pull tests) and freeze-thaw resistance. Five samples should be tested for each, she suggests.

Typical Casting Procedure

The process of casting terra-cotta panels into precast panels is similar to creating panels embedded with thin brick or tile, although some differences exist. Terra-cotta pieces typically are hand set into the panels without the formliners that are used in casting panels with thin-bricks. Ideally, panels can be designed so the forms can be reused, even if the colors of the terra-cotta embeds change. Foam fillers and sealants are applied at the joints so the concrete does not bleed through. Bond breakers are not necessary with terra-cotta pieces.

Reinforcing, lifting hooks, steel anchors, and embeds are installed in typical fashion. The formwork can be stripped within 24 hours, and the precast concrete portions of the panels are acid-washed.

'There are no transportation or erection issues that are distinct to panels embedded with terra-cotta.'

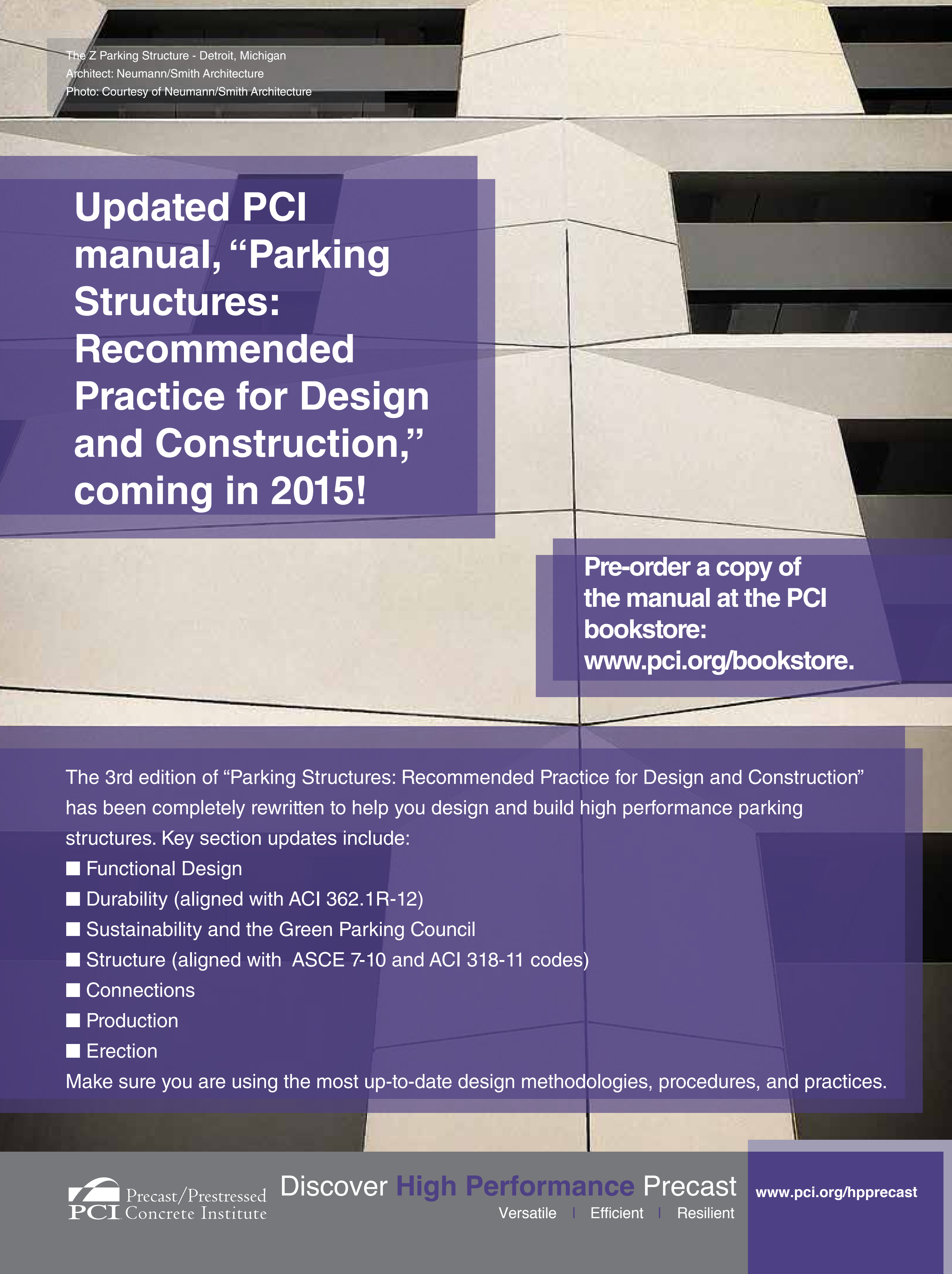
"There are no transportation or erection issues that are distinct to panels embedded with terra-cotta," says NBK's Streff. Terra-cotta panels can be larger and therefore heavier than those with brick, but they are designed at an efficient size for the specific project and can be maneuvered with the right size crane. "There's more attention needed to detailing now, as it's not a set procedure, but otherwise terra-cotta can be designed similar to other clay-faced products."

Terra-cotta can provide a distinctive, unusual appearance, and embedding it in precast concrete creates an efficient, cost-effective approach that is fast to construct and minimizes site congestion. Those involved in the projects agree they will use it again—and have learned from their initial experiences.

"Now that we know what's possible and what can be done, I think I'd push to make the envelope even more thermally efficient on future projects," says Sheldon. "It's important to do your homework and find the best balance. We learned a lot, but we also learned that each project will be a little different."

Vican agrees. "Now that we feel more comfortable designing with terra-cotta on precast concrete panels, and see how much resilience it has, I think we could push the boundaries further next time."

For more information on these or other projects, visit www.pci.org/ascent.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Architect: Neumann/Smith Architecture
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Completed in 1953, the Baha'i House of Worship showcases the intricate details that can be achieved with precast concrete.

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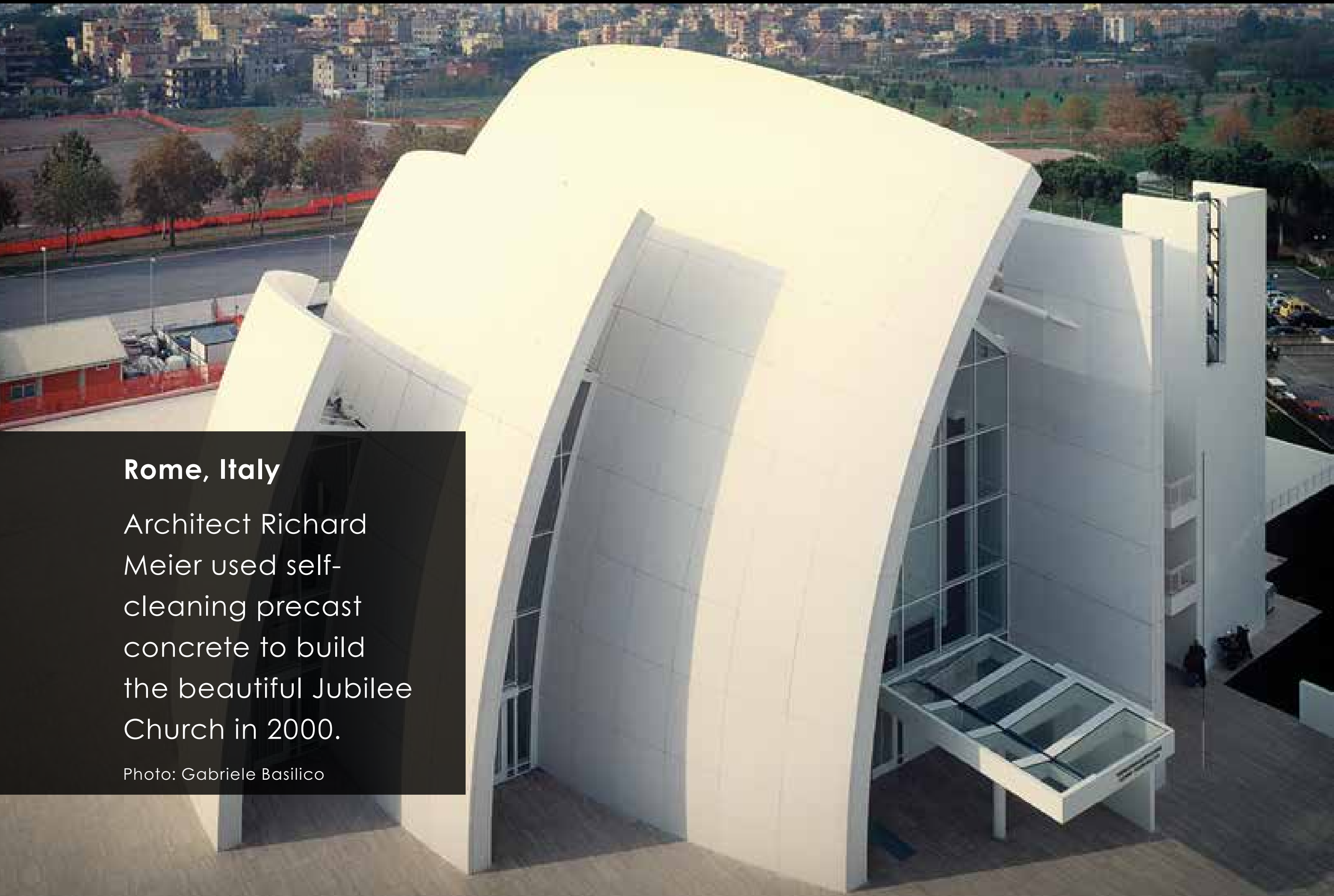

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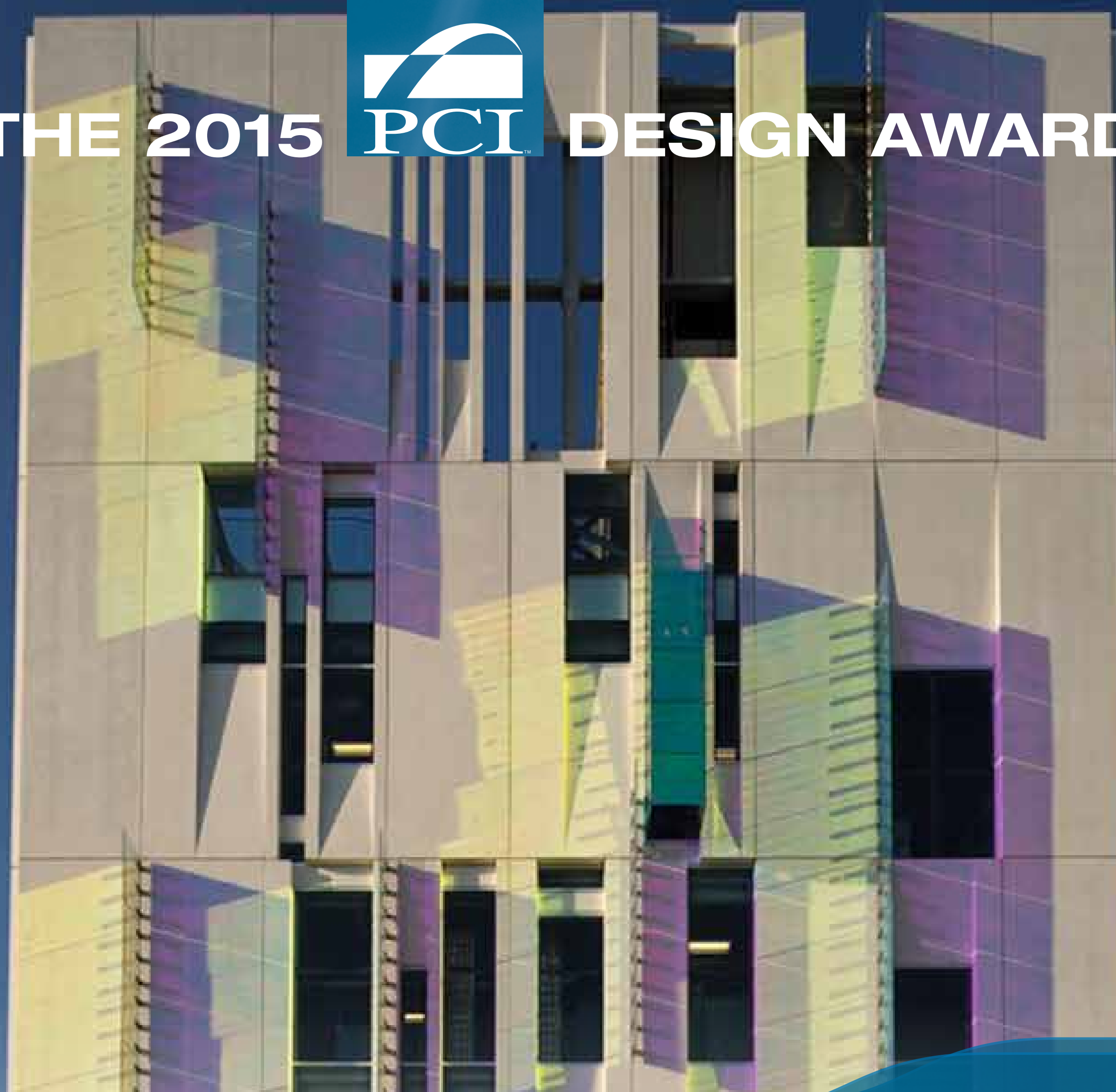

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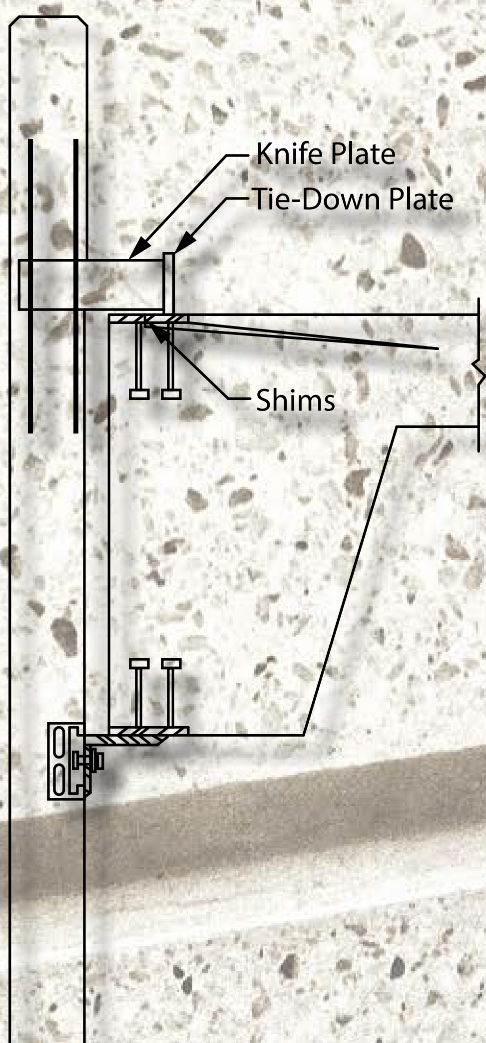

PCI designer's notebook

CONNECTIONS FOR ARCHITECTURAL PRECAST CONCRETE

Connections are a significant design consideration that influences safety, performance, and economy of architectural precast concrete enclosure systems. Many different connection details may be required to accommodate the multitude of sizes and shapes of precast concrete units and varying support conditions.

The purpose of this article is to provide connection design concepts and other considerations to Architects. While connection design is normally delegated to the precast concrete supplier, design criteria and load paths must be specified by the Structural Engineer of Record (SER) and the Architect must be aware of the impact of connections on final detailing.

Whether an architectural precast concrete element is used in a loadbearing or a non-loadbearing application, various forces must be considered in connection design. In non-loadbearing applications, a cladding panel must resist its self weight and all other appropriate forces and loads, such as seismic, wind, snow, restraint of volume changes and effects of support system movement, construction loads, loads from adjacent materials, and any other specified loads. These loads and forces are transferred by the architectural precast concrete element through connections to supporting structure. If a panel is loadbearing, then in addition to the above, some connections must also resist and transfer dead and live loads imposed on it by floor and roof elements.

A major advantage of precast concrete construction is rapid installation. To fully realize this benefit and to maximize economy, field connections should be simple, repetitious, and easy to install. Precast concrete suppliers and erectors have developed preferred connections over the years that suit particular production and/or installation techniques.

Connections should comply with local building codes and satisfy functional and aesthetic requirements, such as recessing for flush floors and/or exposed ceilings. General concepts governing the design, performance, and material requirements of connections can be formulated. For the most effective design, along with efficient connection details, it is recommended that the designer coordinate connection concepts with a precast concrete manufacturer prior to finalizing the plans.

Terminology: The following describes terms common to the precast concrete industry. A precast concrete unit is used to generically represent a wall panel, window panel, spandrel, or column cover that is attached to the main building **structure**. A **connection** is the element that is used to make the attachment of the unit to the structure and will consist of parts embedded in concrete and parts that are field installed, each of which may be called a **connector**. The **body** is the main part of the connection that bridges between a unit and the structure. **Fasteners** are connectors such as bolts or welds used to attach the body to other portions of the connection. The **seat** or **haunch** is the projecting body of a connection from a precast concrete unit upon which the weight of the unit is supported. A **bracket** or **outrigger** is a concrete or steel element projecting from a column or edge beam that supports the seat or haunch from a precast concrete unit and transfers load to the structure. **Shear plates** are field welded connectors that primarily transfer in-plane or out-of-plane horizontal forces to the structure. **Tiebacks** are connections that resist out-of-plane forces due to wind, seismic, and the effect of eccentricity between vertical load and the point of support. **Anchors** are parts of a connection that are embedded in concrete, either in the precast concrete unit or main structure, to transmit forces into the concrete. Anchors typically are headed studs, bolts, or deformed bar anchors. **Post-installed anchors** include expansion or adhesive anchors. **Embedments** are items, usually steel fabrications with anchors, cast into concrete. **Inserts** are usually proprietary items cast into concrete provided in many configurations to serve many different functions. **Adjustable inserts** are proprietary assemblies that have internal adjustability.

Design Coordination

A successful project requires close cooperation and coordination between all participants. With current construction complexity, it is essential to have design input by the precast concrete supplier at an early stage. The supplier will be able to provide suggestions and designs that optimize panel size and joint locations for economy and efficiency.

In the most common contractual arrangement, final structural design of the precast concrete units and final design and detailing of connections of the units to the structure are performed by a Specialty Structural Engineer (SSE) either working for or contracted with the precast concrete supplier. It is imperative that design responsibility be clearly defined in the contract documents.

If the SSE is specified as responsible for the final precast concrete design, the applicable code, design loads, and performance criteria must be specified by the SER in the construction documents. For best coordination, the SER should describe intended load paths. This is best communicated by showing conceptual connections and connection points in the construction documents. For steel frame structures, the SER should determine how far in advance the final connections of the frame and/or floor slabs must be completed prior to precast concrete panel erection. For cast-in-place concrete structures, the SER should determine minimum concrete strength necessary prior to erecting precast concrete units.

The SER will have responsibility to design the supporting and bracing structure to adequately resist the connection forces generated in the precast concrete system. This should include both strength and stiffness. The strength requirement is obvious. In the erection of the precast concrete units, it is assumed that the units can be aligned in accordance with specified erection tolerances when the units are first set. Hence, adequate stiffness is defined by structure deformations that allow erection within tolerance. The best example is multiple panels supported by a beam in a single bay. Sufficient stiffness should be provided so the first panel set does not have to be realigned as subsequent panels are set.

Gravity supports for precast concrete panels ideally transmit vertical load directly to the building columns. However, it is common to locate gravity connections adjacent to columns due to geometric or detailing constraints. In this case, vertical load will be applied to the floor or roof deck structure. Two details are possible. If the gravity connections can be concealed in the interior finish, load will be applied to the edge of the floor slab or roof deck. This generally means that the deck must cantilever some distance over the edge beam. In the precast connection design, it is assumed that the deck cantilever has the strength and stiffness necessary to carry the vertical load and allow panel installation within specified erection tolerances. If the finish will not conceal the gravity connection, a penetration in the edge of the deck will be required and a bracket will have to be provided from the side of the edge beam to accept the gravity load. In this case, eccentric load will be applied to the edge beam and it is assumed that sufficient strength and both flexural and torsional stiffness is provided in the edge beam to carry the vertical load and allow panel installation within the specified erection tolerance. Supplemental framing may be required to accomplish this. The SSE will not evaluate the supporting structure to determine the need for such supplemental framing. This supplemental framing should be supplied and installed with the supporting structure so it is in place at the time of the precast concrete installation. It is generally not feasible to extend gravity connections to the centerline of the edge beam since interior finishes will not cover such a detail.

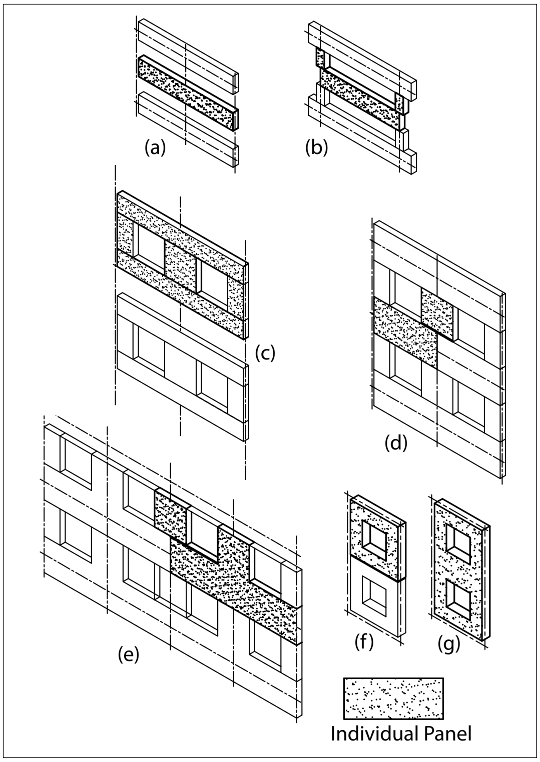

Figure 1 Typical arrangement of precast concrete panels.

Another important role of the SER is to review the precast concrete erection drawings and design work for compatibility with the original intent of the structural design. This is the final opportunity to verify that the SSE has properly interpreted the intent of the construction documents.

Connection Fundamentals

The first step in developing an architectural precast concrete project is establishing panel jointing to use economical panel sizes and coordinate with the floor and column locations in the structure. The second step is to develop the concepts of the connection system so the load points on the structure are coordinated and directions of connection rigidity versus directions of connection flexibility can be set. Beyond these two steps, the work is in the design and detailing.

Figure 1 shows a few of the many possible panel configurations for a wall. Figure 2 illustrates some common connection arrangements for different panel types. Figure 2(a) represents a typical floor-to-floor wall unit. Figures 2(b) and (c) show possible connection locations for a narrow unit, such as a column cover, and Fig. 2(d) shows a wide unit, such as a spandrel. As shown in Fig. 2, panel connections generally consist of two bearing connections and a minimum of four tieback connections. Bearing connections and tieback connections are sometimes combined. Figure 2(d) also shows optional intermediate tieback connections. The primary purpose of intermediate tiebacks is to control concrete tensile stresses due to out-of-plane bending of a panel. These connections may also be used to resist in-plane seismic forces because the connections can be rigid in the direction parallel to the length of the panel without restraining panel shortening due to temperature or shrinkage.

The connection system should not include more than two bearing connections for each panel. Precast concrete panels are very rigid and will not allow a reliable distribution of gravity loads to more than two bearing points. The bearing connections for a given panel should also be located at the same elevation so deflections of supporting frame members do not cause distribution of gravity load different than planned.

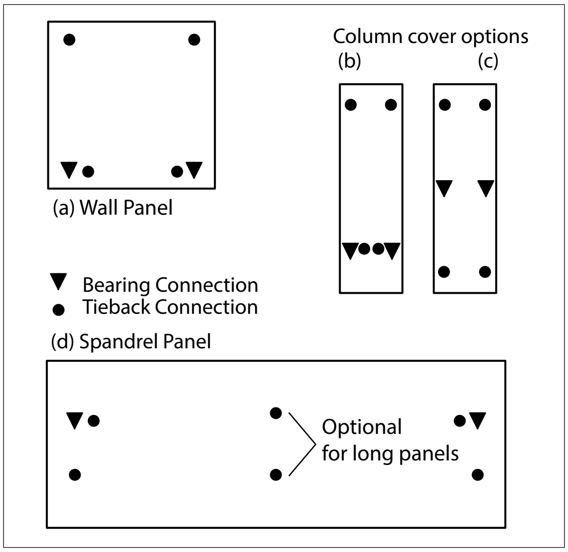

Figure 2 Typical cladding panel connector locations.

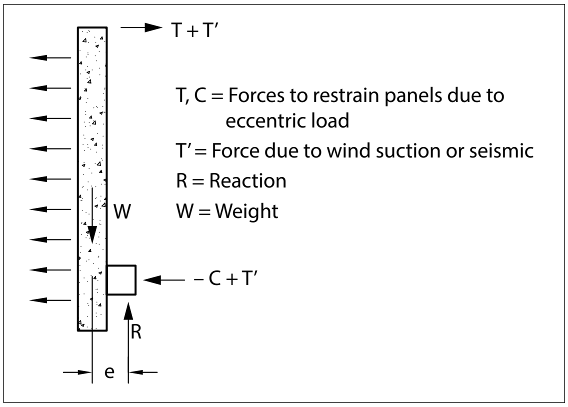

Figure 3 Forces on a panel subjected to wind suction or seismic and eccentric loading.

A panel may be subjected to gravity loads, lateral loads normal to the plane of the panel, and lateral loads in the plane of the panel. For vertical load and out-of-plane load, Fig. 3 illustrates how forces are resolved in gravity and tieback connections to resist the effects of the loads. Note that the tieback connections get components of force directly from the out-of-plane loads plus stabilize the panel when the vertical load is eccentric from the point of vertical support.

As will be discussed in more detail later in the article, panels and structural systems will move due to time dependent changes in the materials, environmental effects, or loads. While connections must have strength and stiffness in the directions that forces are applied, common connection detailing will allow movements in other directions to avoid generating large forces if those movements were restrained. Allowance for movement in connections requires consideration of in-plane movements both horizontally and vertically. Generally, movements out-of-plane are not considered because forces will have to be resisted in the out-of-plane direction. Movement can be allowed by sliding, for example bearings sliding on shim stacks or bolts sliding in slotted holes, or by flexing where a ductile steel element is allowed to bend.

A series of typical connection details with an explanation of the connection function are presented at the end of this article.

Connection Hardware and Materials

Hardware in connections will generally consist of an embedment in the precast concrete unit, an embedment in the supporting structure, a connector element to bridge between the precast concrete unit and the supporting structure, and fastening devices. Anchors into concrete usually consist of reinforcing bars, deformed bar anchors, and headed stud anchors. These anchors are welded to steel shapes such as plates, angles, channels, hollow structural sections, or fabricated steel assemblies to make up an embedment to be cast into concrete. Embedments into the concrete might also include proprietary threaded or weldable inserts.

The connector elements that bridge between the precast concrete unit and the supporting structure are usually flat plates, angles, special steel fabrications, or threaded rods. In welded connections, these elements may be plain pieces. In bolted connections, slotted or oversize holes are generally provided to accommodate field tolerances or provide sliding elements to accommodate movements.

Fastening devices in connections primarily consist of welds or bolts. However, post-installed anchors or grout are occasionally used. Shims are not considered fasteners, but do serve as load transfer devices.

Welded connections are structurally efficient and easily adapted to varying field conditions. Welded connections can be completed only after final alignment.

Hoisting and setting time is critical for economical erection. Welding that must be executed prior to the release of the unit from hoisting equipment should be minimized.

Welding should be performed in accordance with the erection drawings by personnel that have been certified for the welding procedures specified. The type, size, length and location of welds, and any critical sequences should be clearly defined on the erection drawings. All welding, including tack welds, should be made in accordance with the applicable provisions of the American Welding Society (AWS).

Welding on galvanized hardware requires proper procedures to avoid contamination of the weld metal. Cold galvanizing or zinc-rich paint should be applied over welded areas to replace removed galvanizing.

When welding is performed on embedments in concrete, thermal expansion and distortion of the steel may induce cracking or spalling in the surrounding concrete. The extent of cracking and distortion of the metal is dependent on the amount of heat generated during welding and the stiffness of the steel element. Using thicker steel sections can minimize distortion. A minimum of 1/4 in. (6 mm) is recommended for plates. Heat may be reduced by:

1. Use of low-heat welding rods of small diameter.

2. Use of intermittent, rather than continuous, welds.

3. Use of smaller welds and multiple passes.

Some designers specify use of stainless steel connections in highly corrosive environments to prevent long-term corrosion. Welding of stainless steel produces more heat than conventional welding. The increased heat input, plus a higher coefficient of thermal expansion, will create greater cracking potential in the concrete adjacent to embedments. A good detailing solution is to keep embedment edges isolated from adjacent concrete to allow expansion during welding without spalling the concrete. Sealants, sealing foams, clay, or other materials placed around plate edges prior to casting concrete can be used to create this isolation.

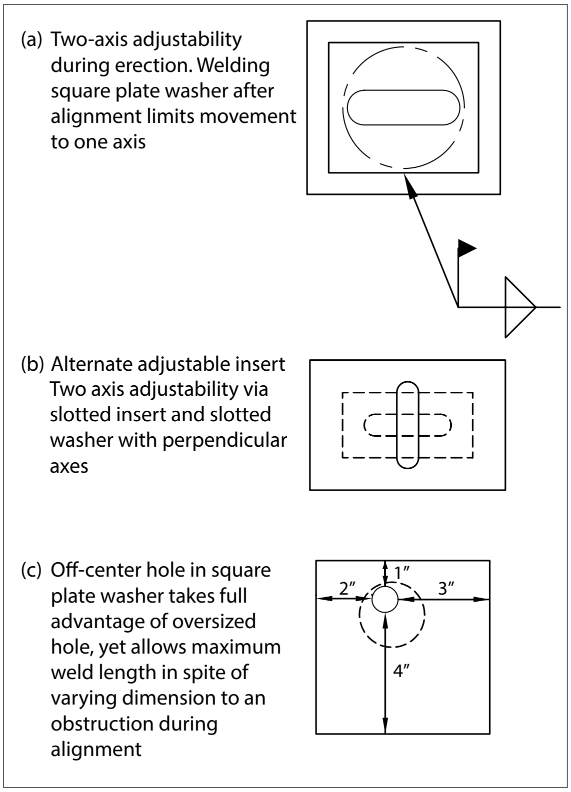

Figure 4 Slotted or oversized holes.

Bolted connections often simplify and speed up erection operations because the connections can resist force immediately upon bolt installation allowing a crane to be released more quickly. When considered in the connection detailing, final alignment and adjustment of the panel can be made at a later time.

Standard bolt sizes used in the industry are 3/4, 1, or 11/4 in. (19, 25, or 32 mm) diameter. High strength bolts are not commonly used. Coil thread stock or coil bolts, which have a coarse thread, are also used. The coarse thread allows quicker installation and is less prone to damage.

Bolted connections must allow for construction tolerances. Slotted or oversized holes accommodate variation and tolerance. (Fig. 4). When slotted holes are also intended to allow structure movements by bolt sliding, the slots must be long enough to account for tolerances plus the amount of planned movement. Plate washers with off-center holes allow maximum flexibility without requiring separate size parts (Fig. 4[c]). For sliding connections, the bolts should be snug, but not so tight to restrict movement within a slot. Low friction washers (Teflon or nylon) may be used to improve movement capability. Roughness at sheared or flame-cut edges should be removed. Bolts should be properly secured, with lock washers, liquid thread locker, or other means to prevent tightening or loosening.

Post-installed anchors, including expansion anchors and adhesive anchors, are often used as connections at foundations or for corrective measures when cast-in inserts are mislocated or omitted. Design provisions are provided in ACI 318, *Building Code Requirements for Structural Concrete*, and may be used if post-installed anchors are qualified in accordance with ACI 355.2 or ACI 355.4. Installation must be in strict conformance with the manufacturer's printed installation instructions.

Expansion anchors are inserted into drilled holes in hardened concrete. Performance of these anchors is dependent on the quality of field workmanship. Strength is obtained by tightening the bolt or nut, thus expanding parts of the anchor, which exert lateral pressure on the concrete. Performance of expansion anchors when subjected to stress reversals, vibrations, or earthquake loading is such that the designer should carefully consider their use for these load conditions.

Adhesive anchors depend on bond of the adhesive to the anchor and bond of the adhesive to the concrete for force transfer. The adhesive may exhibit reduced bond strength at temperatures in the 140 to 150°F (60 to 66°C) range. Such temperatures may be experienced in warm climates, particularly in façade panels with dark aggregates. Similarly, adhesive anchors may not be allowed in fire-rated connection assemblies.

Grouting or drypacking of connections is not widely used, apart from base plates or loadbearing units. The difficulty in maintaining exact elevations and the inability to allow movements and still maintain weather tightness must also be considered. Grouting should be used carefully when installed during temperatures below or near freezing. Units with joints that are to be drypacked are usually supported with shims or leveling bolts until drypack has achieved adequate strength. Shims used for this purpose should be subsequently removed to prevent them from permanently carrying the load or to facilitate joint sealant installation. A dry-packed joint requires a joint wider than 1 in. (25 mm) for best results.

Grouted dowel/anchor bolt connections depend on their diameter, embedded length, and bond developed. Placement of grout during erection usually slows down the erection process. Any necessary adjustment or movement that is made after initial set of the grout may destroy bond and reduce strength. It may be better to provide supplemental bolted connections to expedite erection.

Erection drawings should show the required grout strength:

1. Before erection can continue.
2. Before bracing can be removed.
3. At 28 days.

About AIA Learning Units

Please visit www.pci.org/elearning to read the complete article, as well as to take the test to qualify for 1.0 HSW Learning Unit.

The Precast/Prestressed Concrete Institute (PCI) is a Registered Provider with both the American Institute of Architects (AIA) and the National Council of Examiners for Engineers and Surveyors (NCEES). Continuing education credit is reported to both agencies.

All certificates of completion, for architects and for engineers, will be available from the Registered Continuing Education Provider (RCEP) website at www.rcep.net. PCI reports data twice per month so you should see your credits appear (and your certificate will be ready) within 30 days of our receiving your completed quiz.

If you are new to the Registered Continuing Education Provider system, www.rcep.net will email you a welcome email when PCI uploads your data. That email will contain your account password. Your login name at www.rcep.net will be your email address, so you must include it when submitting your completed quiz.

Instructions

Review the learning objectives below.

Read the AIA Learning Units article. Note: The complete article is avaliable at www.pci.org/elearning.

Complete the online test. You will need to answer at least 80% of the questions correctly to receive the 1.0 HSW Learning Units associated with this educational program.

Learning Objectives:

1. Discuss the various types of precast concrete connections.
2. Understand the design considerations for precast concrete connections.
3. Explain the precast panel-connection-structure interaction.
4. Describe the necessary tolerances and product interfacing.
5. List the broad categories of connection details.

Questions: contact Education Dept. - Alex Morales, (312) 786-0300; Email amorales@pci.org

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PCI eLearning Center

The PCI eLearning Center is the first education management system dedicated to the precast concrete structures industry. This free 24-hour online resource provides an opportunity for architects and engineers to earn continuing education credits on demand. Each course includes a webinar presentation recording, reference materials, and a quiz. Visit this resource at www.pci.org/elearning.

PCI Online Academy–Advancing Professionals

PCI is proud to introduce PCI's Online Academy, a continuing education series for working professionals. Each topic covered consists of weekly lectures that are 90 minutes long. Each course will last from four to six weeks. Continuing education credits will be awarded at the conclusion of each course. Courses are offered via an online delivery system, allowing you to take courses from anywhere in the world! Visit www.pci.org/online-academy for more information.

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Upcoming Seminars and Workshops:

Quality Control Schools

Level I/II
February 24-26
Toronto, Canada

CONTINUING EDUCATION AIA

Additional courses will take place at World of Concrete in Las Vegas, February 2-6, 2015

- Plant Quality Control School, Level I/II
  February 2-4
- Field Quality Control School, CFA
  February 2-4
  Field Quality Control School, CCA
  February 5
- PCI's Presentation: "Quality Assurance - Your Lifeline to a Better Project"
  February 3
  8:30 a.m. - 10:00 a.m.

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PCI's lunch-and-learn/box-lunch programs are a convenient way for architects, engineers, and design professionals to receive continuing education credit without leaving the office. Industry experts visit your location; provide lunch; and present on topics such as sustainability, institutional construction, parking structures, aesthetics, blast resistance, the basics of precast, and many more. Visit www.pci.org/education/box_lunches for a list of lunch-and-learn offerings and to submit a program request.

PCI-Certified Plants

(as of January, 2015)

When it comes to quality, why take chances? When you need precast or precast, prestressed concrete products, choose a PCI-Certified plant. You'll get confirmed capability—a proven plant with a quality assurance program you can count on.

Whatever your needs, working with a PCI plant that is certified in the product groups it produces will benefit you and your project.

- You'll find easier identification of plants prepared to fulfill special needs.
- You'll deal with established producers—many certified for more than 30 years.
- Using quality products, construction crews can get the job done right the first time, keeping labor costs down.
- Quality products help construction proceed smoothly, expediting project completion.

Guide Specification

To be sure that you are getting the full benefit of the PCI Plant Certification Program, use the following guide specification for your next project:

"***Manufacturer Qualification***: The precast concrete manufacturing plant shall be certified by the Precast/Prestressed Concrete Institute Plant Certification Program. Manufacturer shall be certified at time of bidding.

Certification shall be in the following product group(s) and category(ies): [Select appropriate groups and categories (AT or A1), (B1,2,3, or 4), (C1,2,3, or 4), (G)]."

Product Groups and Categories

The PCI Plant Certification Program is focused around four groups of products, designated A, B, C, and G. Products in Group A are audited to the standards in MNL–117. Products in Groups B and C are audited to the standards in MNL–116. Products in Group G are audited according to the standards in MNL–130. The standards referenced above are found in the following manuals:

- MNL–116 *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products*
- MNL–117 *Manual for Quality Control for Plants and Production of Architectural Precast Concrete*
- MNL–130 *Manual for Quality Control for Plants and Production of Glass-Fiber-Reinforced Concrete Products*

Within Groups A, B, and C are categories that identify product types and the product capability of the individual plant. The categories reflect similarities in the ways in which the products are produced. In addition, categories in Groups A, B, and C are listed in ascending order. In other words, a plant certified to produce products in Category C4 is automatically certified for products in the preceding Categories C1, C2, and C3. A plant certified to produce products in Category B2 is automatically qualified for Category B1 but not Categories B3 or B4.

Please note for Group B, Category B1: Some precast concrete products such as highway median barriers, box culverts, and three-sided arches are not automatically included in routine plant audits. They may be included at the request of the precaster or if required by the project specifications.

GROUPS

GROUP A – *Architectural Products*

Category AT – Architectural Trim Units

Wet-cast, nonprestressed products with a high standard of finish quality and of relatively small size that can be installed with equipment of limited capacity such as sills, lintels, coping, cornices, quoins, medallions, bollards, benches, planters, and pavers.

Category A1 – Architectural Cladding and Load-Bearing Units

Precast or precast, prestressed concrete building elements such as exterior cladding, load-bearing and non-load-bearing wall panels, spandrels, beams, mullions, columns, column covers, and miscellaneous shapes. This category includes Category AT.

GROUP B – *Bridges*

Category B1 – Precast Concrete Bridge Products

Mild-steel-reinforced precast concrete elements that include some types of bridge beams or slabs, sheet piling, pile caps, retaining-wall elements, parapet walls, sound barriers, and box culverts.

Category B2 – Prestressed Miscellaneous Bridge Products

Any precast, prestressed element excluding super-structure beams. Includes piling, sheet piling, retaining-wall elements, stay-in-place bridge deck panels, and products in Category B1.

Category B3 – Prestressed Straight-Strand Bridge Members

Includes all superstructure elements such as box beams, I-beams, bulb-tees, stemmed members, solid slabs, full-depth bridge deck slabs, and products in Categories B1 and B2.

Category B4 – Prestressed Deflected-Strand Bridge Members

Includes all products covered in Categories B1, B2, and B3.

GROUP BA – *Bridge Products with an Architectural Finish*

These products are the same as those in the categories within Group B, but they are produced with an architectural finish. They will have a form, machine, or special finish. Certification for Group BA production supersedes Group B in the same category. For instance, a plant certified to produce products in Category B2A is also certified to produce products in Categories B1, B1A, and B2 (while it is not certified to produce any products in B3A or B4A).

GROUP C – *Commercial (Structural)*

Category C1 – Precast Concrete Products

Mild-steel-reinforced precast concrete elements including sheet piling, pile caps, piling, retaining-wall elements, floor and roof slabs, joists, stairs, seating members, columns, beams, walls, spandrels, etc.

Category C2 – Prestressed Hollow-Core and Repetitive Products

Standard shapes made in a repetitive process prestressed with straight strands. Included are hollow-core slabs, railroad ties, flat slabs, poles, wall panels, and products in Category C1.

Category C3 – Prestressed Straight-Strand Structural Members

Includes stemmed members, beams, columns, joists, seating members, and products in Categories C1 and C2.

Category C4 – Prestressed Deflected-Strand Structural Members

Includes stemmed members, beams, joists, and products in Categories C1, C2, and C3.

GROUP CA – *Commercial Products with an Architectural Finish*

These products are the same as those in the categories within Group C, but they are produced with an architectural finish. They will have a form, machine, or special finish. Certification for Group CA production supersedes Group C in the same category. For instance, a plant certified to produce products in Category C2A is also certified to produce products in C1, C1A, and C2 (while it is not certified to produce any products in Groups C3 or C4A).

Group G – *Glass-Fiber-Reinforced Concrete (GFRC)*

These products are reinforced with glass fibers that are randomly dispersed throughout the product and are made by spraying a cement/sand slurry onto molds. This produces thin-walled, lightweight cladding panels.

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ALABAMA

Gate Precast Company, Monroeville (251) 575-2803 ____ A1, C4A
Hanson Pipe and Precast Southeast, Pelham (205) 663-4681 ____ B4, C4

ARIZONA

Coreslab Structures (ARIZ) Inc., Phoenix (602) 237-3875 ____ A1, B4, C4A
CXT Concrete Ties, Tucson (520) 644-5703 ____ C2
Green Fuel Technologies LLC dba Royden Precast, Phoenix (602) 484-0028 ____ B4
TPAC, A Div. of Kiewit Western Co., Phoenix (602) 262-1360 ____ A1, B4, C4A

ARKANSAS

Coreslab Structures (ARK) Inc., Conway (501) 329-3763 ____ C4A

CALIFORNIA

Bethlehem Construction, Inc., Shafter (661) 391-9704 ____ C3A
Clark Pacific, Fontana (909) 823-1433 ____ A1, C3A, G
Clark Pacific, Irwindale (626) 962-8751 ____ C4
Clark Pacific, West Sacramento (916) 371-0305 ____ A1, C3A
Clark Pacific, Woodland (916) 371-0305 ____ A1, B3, C3A
Con-Fab California Corporation, Lathrop (209) 249-4700 ____ B4, C4
Con-Fab California Corporation, Shafter (661) 630-7162 ____ B4, C4
Coreslab Structures (L.A.) Inc., Perris (951) 943-9119 ____ A1, B4, C4A
CTU Precast, Olivehurst (530) 749-6501 ____ A1, C3A
KIE-CON, Inc., Antioch (925) 754-9494 ____ B4, C3
Mid-State Precast, L.P., Corcoran (559) 992-8180 ____ A1, C3A
Oldcastle Precast, Inc., Perris (951) 657-6093 ____ B4A, C2A
Oldcastle Precast Inc., Stockton (209) 466-4212 ____ C2
StructureCast, Bakersfield (661) 833-4490 ____ A1, B3, C3A
Universal Precast Concrete, Inc., Redding (530) 243-6477 ____ A1
Walters & Wolf Precast, Fremont (510) 226-5162 ____ A1, G
Willis Construction Co., Inc., San Juan Bautista (831) 623-2900 ____ A1, C1, G

COLORADO

EnCon Colorado, Denver (303) 287-4312 ____ B4, C2
Plum Creek Structures, Littleton (303) 471-1569 ____ B4, C3A
Rocky Mountain Prestress LLC, Architectural Plant Denver (303) 480-1111 ____ A1, C3A
Rocky Mountain Prestress LLC, Structural Plant, Denver (303) 480-1111 ____ B4, C4
Rocla Concrete Tie, Inc., Pueblo (303) 296-3505 ____ C2
Stresscon Corporation, Colorado Springs (719) 390-5041 ____ A1, B4A, C4A

CONNECTICUT

Blakeslee Prestress Inc., Branford (203) 481-5306 ____ A1, B4, C4A
Coreslab Structures (CONN) Inc., Thomaston (860) 283-8281 ____ A1, B1, C1
Oldcastle Precast, Inc./dba Rotondo Precast, Avon (860) 673-3291 ____ B2, C1A
United Concrete Products, Inc., Yalesville (203) 269-3119 ____ B3, C2

DELAWARE

Concrete Building Systems of Delaware, Inc., Delmar (302) 846-3645 ____ B3, C4
Rocla Concrete Tie, Inc., Bear (302) 836-5304 ____ C2

FLORIDA

Cement Industries, Inc., Fort Myers (239) 332-1440 ____ B3, C3
Colonial Construction, Concrete, Precast, LLC, Placida (941) 698-4180 ____ C2
Coreslab Structures (MIAMI) Inc., Medley (305) 823-8950 ____ A1, C4A
Coreslab Structures (ORLANDO) Inc., Orlando (407) 855-3191 ____ C2
Coreslab Structures (TAMPA) Inc., Tampa (813) 626-1141 ____ A1, B3, C3A
Dura-Stress, Inc., Leesburg (800) 342-9239 ____ A1, B4A, C4A
Finfrock Industries, Inc., Orlando (407) 293-4000 ____ A1, C3
Gate Precast Company, Jacksonville (904) 757-0860 ____ A1, B4, C3A
Gate Precast Company, Kissimmee (407) 847-5285 ____ A1, C3
International Casting Corporation, Miami Lakes (305) 558-3515 ____ C3
Metromont Corporation, Bartow (863) 440-5400 ____ A1, C3A
Pre-Cast Specialties Inc., Pompano Beach (800) 749-4041 ____ C4
Spancrete, Sebring (863) 655-1515 ____ C2
Stabil Concrete Products, LLC, St. Petersburg (727) 321-6000 ____ A1
Standard Concrete Products, Inc., Tampa (813) 831-9520 ____ B4, C3
Structural Prestressed Industries, Medley (305) 556-6699 ____ C4

GEORGIA

Atlanta Structural Concrete Co., Buchanan (770) 646-1888 ____ C4A
Coreslab Structures (ATLANTA) Inc., Jonesboro (770) 471-1150 ____ C2
Metromont Corporation, Hiram (770) 943-8688 ____ A1, C4A
Standard Concrete Products, Inc., Atlanta (404) 792-1600 ____ B4
Standard Concrete Products, Inc., Savannah (912) 233-8263 ____ B4, C4
Tindall Corporation, Georgia Division, Conley (800) 849-6383 ____ C4A

HAWAII

GPRM Prestress, LLC, Kapolei (808) 682-6000 ____ A1, B3, C4

IDAHO

Hanson Structural Precast Eagle, Caldwell (208) 454-8116 ____ A1, B4, C4
Teton Prestress Concrete, LLC., Idaho Falls (208) 523-6410 ____ B4, C3

ILLINOIS

ATMI Precast, Aurora (630) 896-4679 ____ A1, C3A
AVAN Precast Concrete Products, Lynwood (708) 757-6200 ____ A1, C3
County Materials Corporation, Champaign (217) 352-4181 ____ B3, B3-IL
County Materials Corporation, Salem (618) 548-1190 ____ A1, B4, B4-IL, C4
Dukane Precast, Inc., Aurora (630) 355-8118 ____ A1, B3, B3-IL, C3A
Dukane Precast, Inc., Naperville (630) 355-8118 ____ C3
Dukane Precast, Inc., Plainfield, (815) 230-4760 ____ C3
Illini Concrete Company of Illinois, LLC, Tremont (309) 925-5290 ____ B3, B3-IL
Illini Precast, LLC, Marseilles (708) 562-7700 ____ B4, B4-IL, C4
Lombard Architectural Precast Products Co., Alsip (708) 389-1060 ____ A1
Mid-States Concrete Industries, South Beloit (608) 364-1072 ____ A1, B3, B3-IL, C3A
St. Louis Prestress, Inc., Glen Carbon (618) 656-8934 ____ B3, B3-IL, C3
Utility Concrete Products, LLC, Morris (815) 416-1000 ____ B1A, C1A

INDIANA

ATMI Indy, LLC, Greenfield (317) 891-6280 ____ A1, C2A
Coreslab Structures (INDIANAPOLIS) Inc., Indianapolis (317) 353-2118 ____ A1, C4A
Hoosier Precast LLC, Salem (812) 883-4665 ____ B3, C1A
Precast, LLC dba Precast Specialties, Monroeville (260) 623-6131 ____ A1, B1
Prestress Services Industries LLC, Decatur (260) 724-7117 ____ B4, B4-IL, C4A
StresCore, Inc., South Bend (574) 233-1117 ____ C2

IOWA

Advanced Precast Co., Farley (563) 744-3909 ____ A1, C1A
Cretex Concrete Products Midwest, Inc., Iowa Falls (515) 243-5118 A1, B4, B4-IL, C4A
MPC Enterprises, Inc., Mount Pleasant (319) 986-2226 ____ A1, C3A
PDM Precast, Inc., Des Moines (515) 243-5118 ____ A1, C3A

KANSAS

Coreslab Structures (KANSAS) Inc., Kansas City (913) 287-5725 ____ B4, C4
Prestressed Concrete, Inc., Newton (316) 283-2277 ____ A1, B4, C4
Stress-Cast, Inc., Assaria (785) 667-3905 ____ C3A

KENTUCKY

Bristol Group, Inc., Lexington (859) 233-9050 ____ A1, B3A, C3A
de AM - RON Building Systems LLC, Owensboro (270) 684-6226 ____ B3, C3A
Gate Precast Company, Winchester (859) 744-9481 ____ A1, C2A
Prestress Services Industries LLC, Lexington (859) 299-0461 ____ A1, B4, C4A
Prestress Services Industries LLC, Melbourne (859) 441-0068 ____ B4, C3

LOUISIANA

Atlantic Metrocast, Inc., New Orleans (504) 941-3152 ____ C2
Boykin Brothers, Inc./Louisiana Concrete, Baton Rouge (225) 753-8722 ____ A1, B4, C3A
F-S Prestress, LLC, Princeton (318) 949-2444 ____ B4, C3
Fibrebond Corporation, Minden (318) 377-1030 ____ A1, C1A

MAINE

Oldcastle Precast, Auburn (207) 784-9144 ____ B2, C1

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Larry E. Knight, Inc., Glyndon (410) 833-7800 ____ C2
Oldcastle Precast Building Systems Div., Edgewood (410) 612-1213 ____ A1, C3A

MASSACHUSETTS
Oldcastle Precast, Inc./dba Rotondo Precast, Rehoboth (508) 336-7600 ____ B4, C3
Precast Specialties Corp., Abington (781) 878-7220 ____ A1
Unistress Corporation, Pittsfield (413) 499-1441 ____ A1, B4, C4A
Vynorius Prestress, Inc., Salisbury (978) 462-7765 ____ B3, C2

MICHIGAN
International Precast Solutions, LLC, River Rouge (313) 843-0073 ____ A1, B3, C3
Kerkstra Precast Inc., Grandville (800) 434-5830 ____ A1, B3, C3A
M.E.G.A. Precast, Inc., Roseville (586) 294-6430 ____ A1, C3A
M.E.G.A. Precast, Inc., Shelby Township (586) 294-6430 ____ A1, C3
Nucon Schokbeton/Stress-Con Industries, Inc.,
Kalamazoo (269) 381-1550 ____ A1, B4, C3A
Peninsula Prestress Company, Grand Rapids (616) 437-9618 ____ B4, C1
Stress-Con Industries, Inc., Saginaw (989) 239-2447 ____ B4, C3

MINNESOTA
Crest Precast, Inc., La Crescent (507) 895-8083 ____ B3A, C1A
Cretex Concrete Products Midwest, Inc.,
Maple Grove (Elk River) (763) 545-7473 ____ B4, C2
Fabcon Precast, LLC, Savage (800) 727-4444 ____ A1, B1, C3A
Molin Concrete Products Co., Lino Lakes (651) 786-7722 ____ C3A
Wells Concrete, Albany (320) 845-2299 ____ A1, C3A
Wells Concrete, Wells (507) 553-3138 ____ A1, C4A
Wells Concrete–Maple Grove, Osseo (763) 425-5555 ____ A1, C4A

MISSISSIPPI
F-S Prestress, LLC, Hattiesburg (601) 268-2006 ____ B4, C4
Gulf Coast Pre-Stress, Inc., Pass Christian (228) 452-9486 ____ B4, C4
J.J. Ferguson Prestress-Precast Company, Inc., Greenwood (662) 453-5451 ____ B4
Jackson Precast, Inc., Jackson (601) 321-8787 ____ A1, C2A
Tindall Corporation, Moss Point (228) 435-0160 ____ A1, C4A

MISSOURI
Coreslab Structures (MISSOURI) Inc., Marshall (660) 886-3306 ____ A1, B4, C4A
County Materials Corporation, Bonne Terre (573) 358-2773 ____ B4
Mid America Precast, Inc., Fulton (573) 642-6400 ____ A1, B1, C1
Prestressed Casting Co., Ozark (417) 581-7009 ____ C4
Prestressed Casting Co., Springfield (417) 869-1263 ____ A1, C3A

MONTANA
Cretex Concrete Products, Inc., Billings (605) 718-4111 ____ B4, C3
Missoula Concrete Construction, Missoula (406) 549-9682 ____ A1, B3, C3A
Montana Prestressed Concrete - MT City Plant, Montana City (406) 442-6503 ____ B4

NEBRASKA
American Concrete Products Co., Omaha (402) 331-5775 ____ B1A, C1A
Concrete Industries, Inc., Lincoln (402) 434-1800 ____ B4, C4A
Coreslab Structures (OMAHA) Inc., LaPlatte (402) 291-0733 ____ A1, B4, C4A
Enterprise Precast Concrete, Inc., Omaha (402) 895-3848 ____ A1, C2A
Stonco, Inc., Omaha (402) 556-5544 ____ A1

NEW HAMPSHIRE
Newstress Inc., Epsom (603) 736-9348 ____ B3, C3

NEW JERSEY
Boccella Precast LLC, Berlin (856) 767-3861 ____ C2
Jersey Precast, Hamilton (609) 689-3700 ____ B4, C4
Northeast Precast, Millville (856) 765-9088 ____ A1, B3, C3A
Precast Systems, Inc., Allentown (609) 208-1987 ____ B4, C4

NEW MEXICO
Castillo Prestress, Belen (505) 864-0238 ____ B4, C4
Coreslab Structures (ALBUQUERQUE) Inc., Albuquerque (505) 247-3725 ____ A1, B4, C4A
Ferreri Concrete Structures, Inc., Albuquerque (505) 344-8823 ____ A1, C4A

NEW YORK
David Kucera Inc., Gardiner (845) 255-1044 ____ A1, G
Lakelands Concrete Products, Inc., Lima (585) 624-1990 ____ A1, B3A, C3A
Oldcastle Precast Building Systems Div., Selkirk (518) 767-2116 ____ B3, C3A
The Fort Miller Co., Inc., Greenwich (518) 695-5000 ____ B3A, C1
The L.C. Whitford Materials Co., Inc., Wellsville (585) 593-2741 ____ B4, C3

NORTH CAROLINA
Coastal Precast Systems - Wilmington, NC Div., Wilmington (910) 604-2249 ____ B2, C2
Gate Precast Company, Oxford (919) 603-1633 ____ A1, C2
Metromont Corporation, Charlotte (704) 372-1080 ____ A1, C3A
Prestress of the Carolinas, Charlotte (704) 587-4273 ____ B4, C4
Utility Precast, Inc., Concord (704) 721-0106 ____ B3A

NORTH DAKOTA
Wells Concrete, Grand Forks (701) 772-6687 ____ C4A

OHIO
DBS Prestress of Ohio, Huber Heights (937) 878-8232 ____ C3
Fabcon Precast, LLC, Grove City (614) 875-8601 ____ A1, C3A
High Concrete Group LLC, Springboro (937) 748-2412 ____ A1, C3A
KSA, Sciotoville (740) 776-3238 ____ C2
Mack Industries, Inc., Valley City (330) 483-3111 ____ C2
Prestress Services Industries of Ohio, LLC, (I-Beam),
Mt. Vernon (800) 366-8740 ____ A1, B4, C3
Prestress Services Industries of Ohio, LLC,, (Box Beam),
Mt. Vernon (740) 393-1121 ____ B3, C1
Sidley Precast, Thompson (440) 298-3232 ____ A1, C4A

OKLAHOMA
Arrowhead Precast, LLC, Broken Arrow (918) 995-2227 ____ A1, C3A
Coreslab Structures (OKLA) Inc. (Plant No.1), Oklahoma City (405) 632-4944 ____ A1, C4A
Coreslab Structures (OKLA) Inc. (Plant No.2), Oklahoma City (405) 672-2325 ____ B4, C1
Coreslab Structures (TULSA) Inc., Tulsa (918) 438-0230 ____ B4, C4

OREGON
Knife River Corporation, Harrisburg (541) 995-6327 ____ A1, B4, C4
R.B. Johnson Co., McMinnville (503) 472-2430 ____ B4, C3

PENNSYLVANIA
Brayman Precast, LLC, Saxonburg (724) 352-5600 ____ B1, C1
Brayman Precast, LLC, Speers Plant, Saxonburg (724) 352-5600 ____ B1, C1
Concrete Safety Systems, LLC, Bethel (717) 933-4107 ____ A1, B1A, C1A
Conewago Precast Building Systems, Hanover (717) 632-7722 ____ A1, C3A
Dutchland, Inc., Gap (717) 442-8282 ____ C3
Fabcon Precast, LLC, Mahanoy City (570) 773-2480 ____ A1, B1A, C3A
High Concrete Group LLC, Denver (717) 336-9300 ____ A1, B3, C3A
J & R Slaw, Inc., Lehighton (610) 852-2020 ____ A1, B4, C3
Nitterhouse Concrete Products, Inc., Chambersburg (717) 267-4505 ____ A1, C4A
Northeast Prestressed Products, LLC, Cressona (570) 385-2352 ____ B4, C3
PENNSTRESS, Roaring Spring (814) 937-7872 ____ A1, B4, C4
Say-Core, Inc., Portage (814) 736-8018 ____ C2
Sidley Precast, Youngwood (724) 755-0205 ____ C3
Universal Concrete Products Corporation, Stowe (610) 323-0700 ____ A1, C3A
US Concrete Precast Group Mid-Atlantic, Middleburg (570) 837-1774 ____ A1, C3A

RHODE ISLAND
Hayward Baker Inc., Cumberland (401) 334-2565 ____ C2

SOUTH CAROLINA
Florence Concrete Products, Inc., Sumter (803) 775-4372 ____ B4, C3A
Metromont Corporation, Greenville (864) 295-0295 ____ A1, C4A
Tekna Corporation, Charleston (843) 853-9118 ____ B4, C3
Tindall Corporation, Fairforest (864) 576-3230 ____ A1, C4A

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SOUTH DAKOTA

Gage Brothers, Sioux Falls (605) 336-1180 ____ A1, B4, C4A

TENNESSEE

Construction Products, Inc. of Tennessee, Jackson (731) 668-7305 ____ B4, C4
Gate Precast Company, Ashland City (615) 792-4871 ____ A1, C3A
Mid South Prestress, LLC, Pleasant View (615) 746-6606 ____ C3
Prestress Services Industries of TN, LLC, Memphis (901) 775-9880 ____ B4, C3
Ross Prestressed Concrete, Inc., Bristol (423) 323-1777 ____ B4, C3
Ross Prestressed Concrete, Inc., Knoxville (865) 524-1485 ____ B4, C4
Sequatchie Concrete Service, Inc., Chattanooga (423) 867-4510 ____ C2

TEXAS

Coreslab Structures (TEXAS) Inc., Cedar Park (512) 250-0755 ____ A1, C4A
CXT, Inc., Hillsboro (254) 580-9100 ____ B1A, C1A
East Texas Precast Co., LTD., Hempstead (936) 857-5077 ____ C4A
Enterprise Concrete Products, LLC, Dallas (214) 631-7006 ____ B3, C3
Enterprise Precast Concrete of Texas, LLC, Corsicana (903) 875-1077 ____ A1, C1
Gate Precast Company, Hillsboro (254) 582-7200 ____ A1
Gate Precast Company, Pearland (281) 485-3273 ____ C2
GFRC Cladding Systems, LLC, Garland (972) 494-9000 ____ G
Heldenfels Enterprises, Inc., Corpus Christi (361) 883-9334 ____ B4, C4
Heldenfels Enterprises, Inc., San Marcos (512) 396-2376 ____ B4, C4
Legacy Precast, LLC, Brookshire (281) 375-2050 ____ C4
Lowe Precast, Inc., Waco (254) 776-9690 ____ A1, C3A
Manco Structures, Ltd., Schertz (210) 690-1705 ____ C4A
NAPCO PRECAST, LLC, San Antonio (210) 509-9100 ____ A1, C4A
Rocla Concrete Tie, Inc., Amarillo (806) 383-7071 ____ C2
Texas Concrete Partners, LP, Elm Mott (254) 822-1351 ____ B4, C4
Texas Concrete Partners, LP, Victoria (361) 573-9145 ____ B4, C4
Tindall Corporation, San Antonio (210) 248-2345 ____ A1, C3A
Valley Prestress Products Inc., Eagle Lake (979) 234-7899 ____ B4

UTAH

Granite Construction Company, Salt Lake City (801) 526-6000 ____ B1
Hanson Structural Precast Eagle, Salt Lake City (801) 966-1060 ____ A1, B4, C4A, G
Harper Contracting, Salt Lake City (801) 326-1016 ____ B2, C1
Owell Precast LLC, Bluffdale (801) 571-5041 ____ A1, B3A, C3A

VERMONT

Dailey Precast, Shaftsbury (802) 442-4418 ____ A1, B4A, C3A
J. P. Carrara & Sons, Inc., Middlebury (802) 388-6363 ____ A1, B4A, C3A
S.D. Ireland Companies, South Burlington (802) 658-0201 ____ A1, B1, C1

VIRGINIA

Atlantic Metrocast, Inc., Portsmouth (757) 397-2317 ____ B4, C4
Bayshore Concrete Products Corporation, Cape Charles (757) 331-2300 ____ B4, C4
Bayshore Concrete Products/Chesapeake, Inc., Chesapeake (757) 549-1630 ____ B4, C3
Coastal Precast Systems, LLC, Chesapeake (757) 545-5215 ____ A1, B4, C3
Metromont Corporation, Richmond (804) 222-8111 ____ A1, C3A
Rockingham Precast, Inc., Harrisonburg (540) 433-8282 ____ B4
The Shockey Precast Group, Winchester (540) 667-7700 ____ A1, C4A
Tindall Corporation, Petersburg (804) 861-8447 ____ A1, C4A

WASHINGTON

Bellingham Marine Industries, Inc., Ferndale (360) 676-2800 ____ B3, C2
Bethlehem Construction, Inc., Cashmere (509) 782-1001 ____ B1, C3A
Concrete Technology Corporation, Tacoma (253) 383-3545 ____ B4, C4
CXT, Inc., Precast Division, Spokane (509) 921-8716 ____ B1, C1A
CXT, Inc., Rail Division, Spokane (509) 921-7878 ____ C2
EnCon Northwest, LLC, Camas (360) 834-3459 ____ B1A
EnCon Washington, LLC, Puyallup (253) 846-2774 ____ B1, C2
Oldcastle Precast, Inc., Spokane, Spokane Valley (509) 533-0267 ____ A1, B4, C4
Wilbert Precast, Inc., Yakima (509) 248-1984 ____ B3, C3

WEST VIRGINIA

Carr Concrete Corporation, Williamstown Road (800) 837-8918 ____ B4, C3
Eastern Vault Company, Inc., Princeton (304) 425-8955 ____ B3, C3

WISCONSIN

County Materials Corporation, Eau Claire (800) 729-7701 ____ B4
County Materials Corporation, Janesville (608) 373-0950 ____ B4, B4-IL
County Materials Corporation, Roberts (800) 426-1126 ____ B4, C3
International Concrete Products, Inc., Germantown (262) 242-7840 ____ A1, C1
KW Precast, LLC, Burlington (262) 767-8700 ____ B4, B4-IL, C4
MidCon Products, Inc., Hortonville (920) 779-4032 ____ A1, C
Spancrete, Valders (920) 775-4121 ____ A1, B4, C3A
Stonecast Products, Inc., Germantown (262) 253-6600 ____ A1, C1
Wausau Tile Inc., Rothschild (715) 359-3121 ____ AT

WYOMING

voestalpine Nortrak Inc., Cheyenne (509) 220-6837 ____ C2

MEXICO

PRETECSA, S.A. DE C.V., Atizapan De Zaragoza (011) 52-10360777 ____ A1, G
Willis De Mexico S.A. de C.V., Tecate (011) 52-665-655-2222 ____ A1, C1, G

CANADA

BRITISH COLUMBIA

APS Architectural Precast Structures LTD, Langley (604) 888-1968 ____ A1, B4, C3
Armtec Limited Partnership, Richmond (604) 278-9766 ____ A1, B4, C3

NEW BRUNSWICK

Strescon Limited, Saint John (506) 633-8877 ____ A1, B4, C4A

NOVA SCOTIA

Strescon Limited, Beford (902) 494-7400 ____ A1, B4, C4A

ONTARIO

Artex Systems Inc., Concord (905) 669-1425 ____ A1
Global Precast INC, Maple (905) 832-4307 ____ A1
Prestressed Systems, Inc., Windsor (519) 737-1216 ____ B4, C4

QUEBEC

Betons Prefabriques du Lac, Inc., Bombardier Plant, Alma (418) 668-6161 ____ A1, C2
Betons Prefabriques du Lac, Inc., Papeterie Plant, Alma (418) 668-6161 ____ A1, C3A, G
Betons Prefabriques Trans. Canada Inc.,
St. Eugene De Grantham (819) 396-2624 ____ A1, B4, C3A
Prefab De Beauce, Sainte-Marie De Beauce (418) 387-7152 ____ A1, C3

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PCI-Qualified & PCI-Certified Erectors

(as of January, 2015)

When it comes to quality, why take chances? When you need precast or precast, prestressed concrete products, choose a PCI-Qualified/Certified Erector. You'll get confirmed capability with a quality assurance program you can count on.

Whatever your needs, working with an erector who is PCI Qualified/Certified in the structure categories listed will benefit you and your project.

- You'll find easier identification of erectors prepared to fulfill special needs.
- You'll deal with established erectors.
- Using a PCI-Qualified/Certified Erector is the first step toward getting the job done right the first time, thus keeping labor costs down.
- PCI-Qualified/Certified Erectors help construction proceed smoothly, expediting project completion.

Guide Specification

To be sure that you are getting an erector from the PCI Field Certification Program, use the following guide specification for your next project:

"Erector Qualification: The precast concrete erector shall be fully qualified or certified by the Precast/Prestressed Concrete Institute (PCI) prior to the beginning of any work at the jobsite. The precast concrete erector shall be qualified or certified in Structure Category(ies): [Select appropriate groups and categories S1 or S2 and/or A1]."

Erector Classifications

The PCI Field Certification Program is focused around three erector classifications. The standards referenced are found in the following manuals:

MNL–127 *Erector's Manual - Standards and Guidelines for the Erection of Precast Concrete Products*

MNL–132 *Erection Safety Manual for Precast and Prestressed Concrete*

GROUPS

Category S1 - Simple Structural Systems

This category includes horizontal decking members (e.g., hollow-core slabs on masonry walls), bridge beams placed on cast-in-place abutments or piers, and single-lift wall panels.

Category S2 - Complex Structural Systems

This category includes everything outlined in Category S1 as well as total-precast, multi-product structures (vertical and horizontal members combined) and single- or multistory load-bearing members (including those with architectural finishes).

Category A - Architectural Systems

This category includes non-load-bearing cladding and GFRC products, which may be attached to a supporting structure.

Certified erectors are listed with an asterisk.

ARIZONA

Coreslab Structures (ARIZ), Inc., Phoenix (602) 237-3875 ____ S2, A
RJC Contracting, Inc., Mesa (480) 357-0868 ____ S1
TPAC, Phoenix (602) 262-1360 ____ S2, A

CALIFORNIA

Walters & Wolf Precast, Fremont (510) 226-9800 ____ A

COLORADO

Gibbons Erectors, Inc., Englewood (303) 841-0457 ____ S2, A
Rocky Mountain Prestress,LLC, Denver (303) 480-1111 ____ S2, A

CONNECTICUT

* **Blakeslee Prestress, Inc.,** Branford (203) 481-5306 ____ S2

FLORIDA

All Florida Erectors and Welding, Inc., Apopka (407) 466-8556 ____ S2, A
Concrete Erectors, Inc., Altamonte Springs (407) 862-7100 ____ S2, A
Finfrock Industries, Inc., Apopka (407) 293-4000 ____ S2, A
* **Florida Builders Group, Inc.,** Miami (305) 278-0098 ____ S2
* **Jacob Erecting & Construction, LLC,** Jupiter (561) 741-1818 ____ S2, A
James Toffoli Construction Company, Inc., Fort Myers (239) 479-5100 ____ S2, A
* **Pre-Con Construction of Tampa Inc./Pre-Con Construction, Inc.,** Tampa (813) 626-2545 ____ S2, A
Prestressed Contractors Inc., West Palm Beach (561) 741-4369 ____ S1
* **Spancrete Southeast,** Sebring (863) 655-1515 ____ S1
* **Specialty Concrete Services, Inc.,** Umatilla (352) 669-8888 ____ S2, A

GEORGIA

Bass Precast Erecting, Inc., Cleveland (706) 809-2781 ____ S2, A
Jack Stevens Welding LLP, Murrayville (770) 534-3809 ____ S2
Rutledge & Sons, Inc., Canton (770) 592-0380 ____ S2

IDAHO

* **Precision Precast Erectors, LLC,** Worley (208) 231-5650 ____ S2, A

ILLINOIS

Area Erectors, Inc., Rochelle (815) 562-4000 ____ S2, A
Mid-States Concrete Industries, South Beloit (815) 389-2277 ____ S2, A

IOWA

Industrial Steel Erectors, Davenport (563) 355-7202 ____ S1
Northwest Steel Erection, Inc., Grimes (515) 986-0380 ____ S1

KANSAS

* **Carl Harris Co., Inc.,** Wichita (316) 267-8700 ____ S2, A
Crossland Construction Company, Inc., Columbus (620) 442-1414 ____ S2, A
Ferco, Inc., Salina (785) 825-6380 ____ S1

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MARYLAND

DLM Contractors, LLC, Cheltenham (301) 877-0000 — S2, A
E & B Erectors, Inc., Elkridge (410) 360-7800 — S2, A
E.E. Marr Erectors, Inc., Baltimore (410) 837-1641 — S2, A
* L.R. Willson & Sons, Inc., Gambrills (410) 987-5414 — S2, A

MASSACHUSETTS

* Atlantic Bridge & Engineering, Salisbury (978) 465-4337 — S1
* Prime Steel Erecting, Inc., North Billerica (978) 671-0111 — S2, A
The Middlesex Corporation, Littleton (860) 206-4404 — S2

MICHIGAN

Assemblers Precast & Steel Services, Inc., Saline (734) 368-6147 — S2, A
Devon Contracting, Inc., Detroit (313) 221-1550 — S2, A
G2 Inc., Cedar Springs (616) 696-9581 — S2, A
Midwest Steel, Inc., Detroit (313) 873-2220 — S2
* Pioneer Construction Inc., Grand Rapids (616) 247-6966 — S2

MINNESOTA

* Amerect, Inc., Newport (651) 459-9909 — A
Fabcon Precast, LLC, Savage (952) 890-4444 — S2
* Landwehr Construction Inc., St. Cloud (320) 252-1494 — S2, A
Molin Concrete Products Company, Lino Lakes (651) 786-7722 — S2, A
* Wells Concrete, Wells (800) 658-7049 — S2, A
Wells Concrete, Maple Grove (763) 425-5555 — S2, A

MISSISSIPPI

Bracken Construction Company, Inc., Jackson (601) 922-8413 — S2, A

MISSOURI

JE Dunn Construction, Kansas City (816) 292-8762 — S2, A
* Prestressed Casting Co., Springfield (417) 869-7350 — S2, A

NEBRASKA

Structural Enterprises Inc., Lincoln (402) 423-3469 — S2
Topping Out Inc. dba Davis Erection–Omaha, Omaha (800) 279-1201 — S2

NEW HAMPSHIRE

* American Steel & Precast Erectors, Greenfield (603) 547-6311 — S2, A
* Newstress, Inc., Epsom (603) 736-9000 — S2

NEW JERSEY

CRV Precast Construction LLC, Eastampton (609) 518-6810 — S2, A
J. L. Erectors, Inc., Blackwood (856) 232-9400 — S2, A
* JEMCO-Erectors, Inc., Shamong (609) 268-0332 — S2, A
Jonasz Precast, Inc., Westville (856) 456-7788 — S2, A

NEW MEXICO

Structural Services, Inc., Albuquerque (505) 345-0838 — S2, A

NEW YORK

Koehler Masonry, Farmingdale (631) 694-4720 — S2
Oldcastle Building Systems Div. / Project Services, Selkirk (518) 767-2116 — S2, A
* The L.C. Whitford Co., Inc., Wellsville (585) 593-2741 — S2

NORTH CAROLINA

* Carolina Precast Erectors, Inc., Taylorsville (828) 217-1115 — S2, A
Tindall Corporation, Spartanburg (864)576-3230 — S2

NORTH DAKOTA

Comstock Construction, Wahpeton (701) 892-7236 — S2
PKG Contracting, Inc., Fargo (701) 232-3878 — S2

OHIO

* Precast Services, Inc., Twinsburg (330) 425-2880 — S2, A
Sidley Precast Group, A Division of R.W. Sidley, Inc., Thompson (440) 298-3232 — S2, A

OKLAHOMA

Allied Steel Construction Co., LLC, Oklahoma City (405) 232-7531 — S2, A

PENNSYLVANIA

Century Steel Erectors, Kittanning (724) 545-3444 — S2, A
* Conewago Precast Building Systems, Hanover (717) 632-7722 — S2, A
* High Structural Erectors, LLC, Lancaster (717) 390-9203 — S2, A
* Kinsley Construction Inc. t/a Kinsley Manufacturing, York (717) 757-8761 — S1
Maccabee Industrial, Inc., Belle Vernon (724) 930-7557 — S2, A
Nitterhouse Concrete Products, Inc., Chambersburg (717) 267-4505 — S2, A

SOUTH CAROLINA

Davis Erecting & Finishing, Inc., Greenville (864) 220-0490 — S2, A
Tindall Corporation, Fairforest (864) 576-3230 — S2

TENNESSEE

Mid South Prestress, LLC, Pleasant View (615) 746-6606 — S2

TEXAS

* Coreslab Structures (TEXAS) Inc., Cedar Park (512) 250-0755 — S2, A
Derr and Isbell Construction, LLC, Euless (817) 571-4044 — S2, A
Gulf Coast Precast Erectors, LLC, Hempstead (832) 451-4395 — S2
Precast Erectors, Inc., Hurst (817) 684-9080 — S2, A

UTAH

* IMS Masonry, Lindon (801) 796-8420 — A

VIRGINIA

* The Shockey Precast Group, Winchester (540) 667-7700 — S2, A

WASHINGTON

* Oldcastle Precast, Inc., Spokane, Spokane Valley (509) 536-3330 — S2, A

WISCONSIN

* J.P. Cullen, Janesville (608) 754-6601 — S1, A
Miron Construction Co. Inc., Neenah (920) 969-7000 — S2, A
* Spancrete, Valders (920) 775-4121 — S2, A

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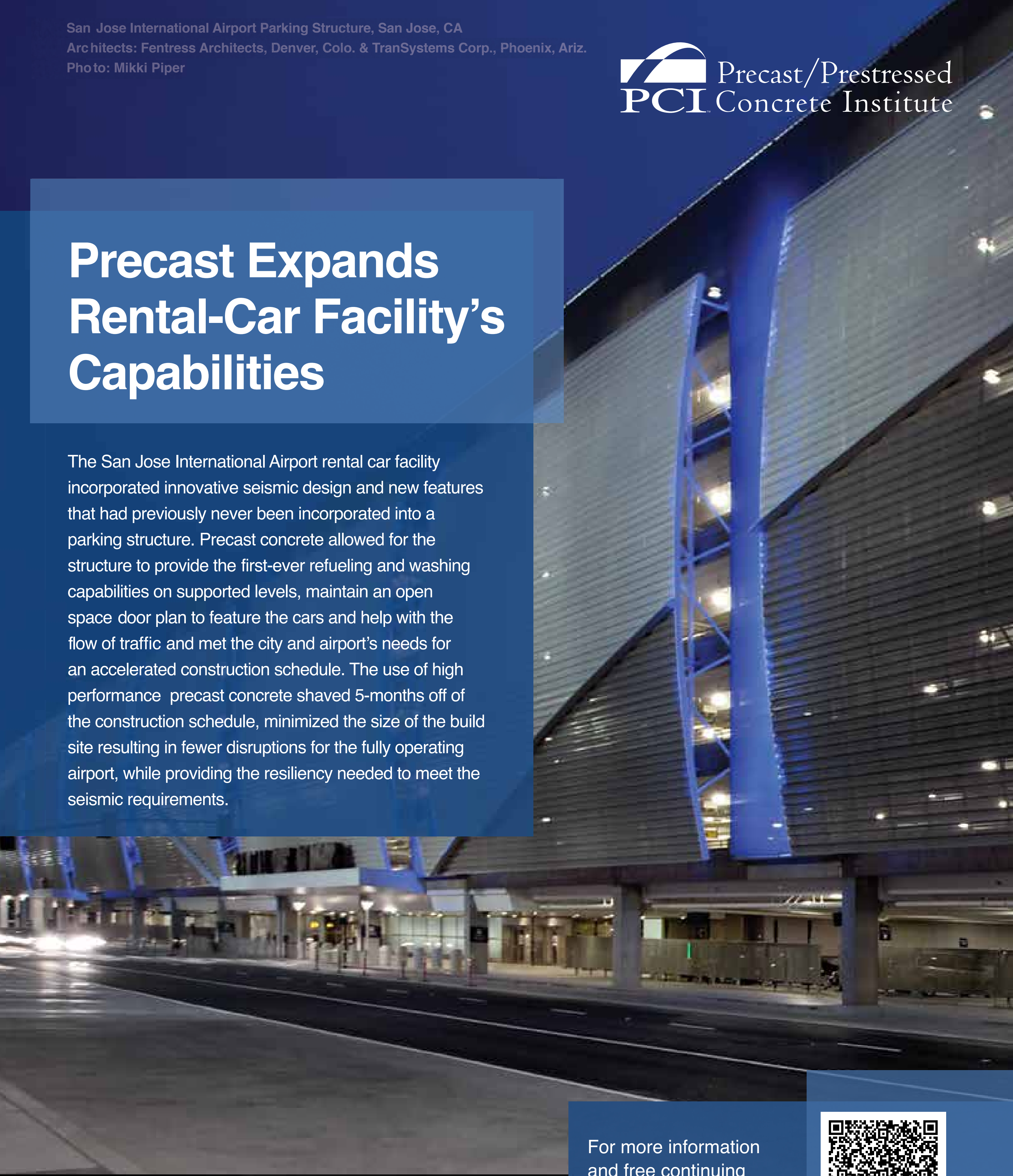

San Jose International Airport Parking Structure, San Jose, CA
Architects: Fentress Architects, Denver, Colo. & TranSystems Corp., Phoenix, Ariz.
Photo: Mikki Piper

Precast/Prestressed Concrete Institute

Precast Expands Rental-Car Facility's Capabilities

The San Jose International Airport rental car facility incorporated innovative seismic design and new features that had previously never been incorporated into a parking structure. Precast concrete allowed for the structure to provide the first-ever refueling and washing capabilities on supported levels, maintain an open space door plan to feature the cars and help with the flow of traffic and met the city and airport's needs for an accelerated construction schedule. The use of high performance precast concrete shaved 5-months off of the construction schedule, minimized the size of the build site resulting in fewer disruptions for the fully operating airport, while providing the resiliency needed to meet the seismic requirements.

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Lincoln East Parking Garage, Miami Beach, FL
Architect: Ten Arquitectos
Photo Credit: Miami in Focus, Inc.

Dash of Flash

The Lincoln East Parking Garage sits in the center of Miami's vibrant artistic, cultural retail district in South Beach which excites ones artistic imagination. The architect used the aesthetic versatility of precast to redefine the utilitarian garages of old. The art-deco perforated precast allows light to penetrate to the interior during the day and a welcoming glow at night. Drawing inspiration from the signature curving property lines of the historic district, precast was the natural choice for this cutting-edge design.

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San Jose International Airport Parking Structure, San Jose, CA
Architects: Fentress Architects, Denver, Colo. & TranSystems Corp., Phoenix, Ariz.
Photo: Mikki Piper

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