RESILIENCY ISSUE

SUMMER 2013

ASCENT®

DESIGNING WITH PRECAST

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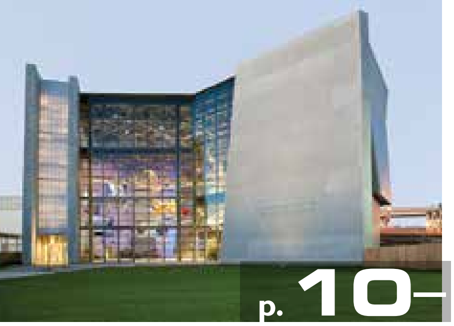

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Precast Inherently Provides Resiliency

High-performance structures are enhanced by the inherent benefits provided by precast concrete, such as storm protection, seismic, blast and fire resistance, and acoustic control.

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Resiliency—An Important Part of High Performance

Brian Miller, P.E., LEED AP
Executive Editor
bmiller@pci.org

When people think of High Performance, the versatility, efficiency, and durability of the components come to mind. These relate to the construction and operations of a structure, which are critical aspects. But there is another key ingredient to a truly high-performance structure: Resiliency.

Creating a true high-performance structure challenges designers and contractors to integrate and optimize all relevant systems and materials to minimize costs, energy usage, and maintenance over the building's service life. A big part of this consists of designing projects to be resilient.

Resiliency goes beyond durability, which is essentially the building's ability to withstand the routine environmental conditions to which it is subjected. Resiliency refers to the ability of a project to withstand less frequent extreme events such as hurricanes, tornados, earthquakes, explosions, and fires. These events can result in the complete destruction of a structure and devastate a community.

Resiliency also is a natural extension of sustainability, which is often defined as the ability to meet our needs and goals while not compromising or inhibiting future generations from doing the same. When we build resilient structures, we typically do not need to use more materials and energy to rebuild them again after an extreme event. Even more important, we save lives.

Precast concrete inherently provides a high level of resiliency, mostly due to its strength, mass, and durable nature. For example, most precast concrete has at least 5000 psi compressive strength, which can resist greater wind loads than common stick-built construction. Precast also uses welded and bolted connections, versus the nails, screws, and mortar used in more traditional methods.

Precast concrete can be further designed to resist the forces created by extreme events. Often this involves the special design of connections, so they transmit or absorb additional forces. It may also include sacrificial reinforcement, such as in precast hybrid moment frames.

Precast concrete is one of the most resilient building systems, providing protection for occupants and equipment. It also helps to maintain functionality of a structure after an extreme event. It serves as a great example of a high-performance material that integrates and optimizes many attributes into one system.

The articles in this issue focus on the inherent resiliency of precast concrete. They showcase projects from around the country that have used precast concrete systems to provide high-performance attributes to a range of building types. We hope this issue gives you ideas on how you can use precast concrete's resiliency to meet your own high-performance needs. Let's Discover High Performance Precast!

ASCENT **On the cover: James F. Battin United States Courthouse in Billings, Mont.**

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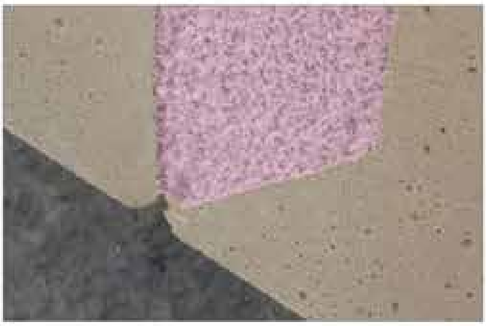
- **POSTMASTER:** Send address changes to *Ascent*, 200 W. Adams St., Suite 2100, Chicago, IL 60606. Periodical postage paid at Chicago, IL and additional mailing offices.
- *Ascent* (Vol. 23, No. 3, ISSN 10796983) is published quarterly by the Precast/Prestressed Concrete Institute, 200 W. Adams St., Suite 2100, Chicago, IL 60606.

- If you have a project to be considered, send information to Brian Miller, Executive Editor, bmiller@pci.org

At Pomona College, the students aren't the only ones earning high marks!



In October 2011, Southern California's Pomona College proudly announced the achievements and national recognition earned by two recent additions to campus - the new Sontag and Pomona dormitories.

Opened in the Summer of 2011, the dorms had been designed to meet the highest standards of sustainable and environmentally conscious construction using features such as rooftop solar panels, low-flow water fixtures, energy efficient lighting, and a solar-heated hot water system predicted to provide 80 percent of the buildings' needs.

Another key component was concrete sandwich walls insulated with Thermomass System NC. Built by Clark Pacific, the high performance precast panels created a durable and resilient exterior wall with continuous insulation, no thermal bridges and an R-value nearly twice that of California's stringent energy code.

In all, the energy saving components and sustainable construction techniques resulted in a LEED Platinum certification for both of the new dormitories - a first for California, and only the second large-scale residence project in the nation to earn such a distinction.

By adhering to a philosophy of high standards, environmental conservation, and attention to detail, Pomona College is setting an example that reaches well beyond its classrooms.

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Design Awards Winner Site Available in August

CHICAGO, ILLINOIS

Each year, PCI hold its annual Design Awards competition. The competition recognizes design excellence and construction quality using precast concrete. This year, 20 projects were selected as winners in a variety of categories including structures, transportation, and high performance.

View photos and details of the winning projects by visiting www.pci.org and clicking on 2013 Design Awards. A summary article of the winning projects will be in the fall issue of *Ascent*. The submission site for the 52st Annual PCI Design Awards will open in January 2014.

High Concrete Group Provides Precast Concrete Components for Hockey Arena Parking Structure

DENVER, PENNSYLVANIA

High Concrete Group LLC is producing precast concrete coponents for an eight-story parking structure adjacent to the new PPL Center Arena in Allentown, Pa., the future home of the American Hockey League's Lehigh Valley Phantoms. The new parking structure will be 242,300 sq. ft and will accommodate visitors to the PPL Center. The overall project is scheduled for completion in late summer 2014.

Registration is Open for the 2013 PCI Convention and National Bridge Conference

CHICAGO, ILLINOIS

The PCI Convention and National Bridge Conference is going High Performance in 2013. The event will take place September 21-24 in Grapevine, Texas, and provide attendees an opportunity to take their companies to the next level. The event will offer a number of ways to expand your knowledge, learn about new products and technologies, and develop vital relationships. It is the premier, must-attend annual event for the precast concrete structures industry.

Spancrete Wins Inaugural Eureka Award for Innovation in Precast Concrete

WAUKESHA, WISCONSIN

*The Business Journa*l recently announced Spancrete as a winner in the inaugural Eureka Award. Spancrete received the award in the Design category for the company's Innovation in the Precast Concrete Industry: Pervious Concrete Systems entry.

Spancrete recently introduced the industry's first-ever, slip-formed pervious precast concrete systems that effectively filter stormwater to reduce runoff and pollutants from entering streams, rivers, and wastewater treatment facilities.

The Eureka Awards recognize innovation and creativity in business, education, the arts, and other programs for businesses, individuals, and organizations throughout the Milwaukee, Wis., area.

Congratulations to the Winner of PCI's Survey at the 2013 AIA National Convention and Design Expo

CHICAGO, ILLINOIS

PCI exhibited at the 2013 AIA National Convention and Design Expo, June 19-21 in Denver, Colo. Architects who stopped by the PCI booth were asked to take a quick survey to be entered into a drawing to win a $500 Visa gift card. Congratulations to Grant Gustafson of NBBJ, who won the survey drawing and will receive a $500 gift card. Dave Dresher of GLMV Architecture was the runner-up and will receive a $250 gift card.

Marty McIntyre Named PCI Foundation Executive Director

CHICAGO, ILLINOIS

The PCI Foundation named Marty McIntyre as its executive director. McIntyre came from the PCI of Illinois and Wisconsin chapter and will provide development, marketing, and program support for the PCI Foundation in her new

Martin Clarke of the British Precast Concrete Federation Awarded OBE

LEICESTER, U.K.

Martin Clarke, chief executive of the British Precast Concrete Federation, has been awarded Officer of the Most Excellent Order of the British Empire (OBE) in the Queen's birthday honors list for services to industry. This honor is one of the five ranks of official recognition in Great Britain, the top two of which are knighthood.

Submit your headline news for consideration in a future issue of *Ascent* to Brian Miller at bmiller@pci.org.

Precast Inherently Provides Resiliency

High-performance structures are enhanced by the inherent benefits provided by precast concrete, such as storm protection, seismic, blast and fire resistance, and acoustic control

— Craig A. Shutt

In recent years, building owners have become more aware of the dangers posed by natural and man-made forces that can impact their tenants and structures. Designers must increasingly take into account factors such as harsher and more frequent storms and terrorist threats when designing all types of structures. To meet these needs, they often turn to precast concrete structural and envelope systems, as they provide inherent protection against multiple hazards.

Natural Forces

Precast concrete designs offer protection against such natural disasters as storms and floods, earthquakes, hurricanes, and tornados or other high-wind situations. Considering these benefits early in the design process, and working with a precaster to understand the material's capabilities, maximizes precast concrete's effectiveness against each of these events.

High winds pose two threats: the wind load itself and flying debris, which essentially become projectiles or missiles that travel at speeds of more than 100 mph. It's the second threat that does tremendous damage as envelope systems are compromised. Precast concrete's ability to protect against wind-borne debris has been well proven in independent tests. Precast's strength and durability also provides protection against storm surge resulting from a hurricane.

Precast structural components can also be designed to resist seismic forces and remain standing after even the most severe earthquakes. Extensive research has been done on unbonded, post-tensioned precast shear wall and hybrid moment frame systems. Several of these concepts have been adopted into standards such as ACI-318 which is referenced by the International Building Code. These options allow designers to meet seismic-related design challenges, in most types of buildings nationwide.

Precast concrete structural systems also can help restore a building to full functionality with minimal labor and resources after a major event such as an earthquake or hurricane. This capability helps minimize negative effects to the environment due to reduced reconstruction and downtime, since resilient structures do not need to be completely rebuilt.

Man—made Forces

Buildings also need to resist a variety of man-made forces, such as fires and explosions. Whether improving blast protection for any building or meeting specific Anti-Terrorism/Force Protection requirements for government buildings, precast concrete can provide the needed design attributes. Durable architectural precast concrete panels can mitigate shock waves, connections in structural precast concrete can protect against progressive collapse, and decorative precast concrete barriers can protect the building's perimeter.

High-performance precast concrete also protects against fire and fire suppression damages. Its inorganic composition ensures it will not combust, providing passive fire protection. That allows it to easily achieve required fire ratings, slow the spread of fire, remain structurally intact, and allow reuse of the panels afterward. Precast concrete is also less damaged from sprinkler activations and fire department actions to bring a fire under control.

Other indoor environmental quality (IEQ) benefits can also accrue from precast concrete's attributes. It prevents mold growth, protects construction materials against moisture through faster construction, and eliminates the need to add drywall to interior walls. It also does not need additional treatment to provide adequate sound insulation to achieve required sound transmission or impact-insulation class ratings due to its density.

High-performance precast concrete offers owners and designers many benefits to help create a safe, secure, and productive environment for tenants and building users. The following examples show ways in which precast concrete's resiliency helped meet a variety of owner needs in a wide range of building types often with minimal changes to conventional design.

Architectural precast concrete panels inset with a terra-cotta veneer helped the new 172,000-square-foot Public Safety Building in Salt Lake City meet a variety of goals, including aesthetic design, safety, and seismic needs. All photos: The Exoro Group and GSBS.

PROJECT SPOTLIGHT

Public Safety Building

Location: Salt Lake City, Utah

Project Type: Police and fire headquarters

Size: 172,000 square feet, plus 143,000-square-foot, two-story, below-grade parking structure

Cost: $85 million

Project Management: MOCA Systems, Salt Lake City, Utah

Designer: GSBS Architects, Salt Lake City, Utah, and MWL Architects and Planners (McClaren, Wilson & Lawrie Inc.), Phoenix, Ariz.

Owner: Salt Lake City Corp., Salt Lake City, Utah

Structural Engineer: Dunn Associates Inc., Salt Lake City, Utah

Construction Management: Okland Construction Co., Salt Lake City, Utah

PCI-Certified Precaster: Hanson Structural Precast, Salt Lake City, Utah

Precast Components: Insulated wall panels

Public Safety Building

Salt Lake City officials set high standards when they planned their new Public Safety Building. The four-story facility needed to house police and fire facilities, central dispatch, emergency operations, and a state-of-the-art media-communications center.

As the center for first responders in an emergency, the building had to protect against both natural and man-made forces that could disrupt response time. This required designers to build in fire, blast, seismic, and other protections while also creating a welcoming facility for visitors. The building also had to achieve high LEED standards, with a goal of becoming the first public-safety building in the country to achieve Net Zero energy use.

To help meet these needs, designers clad the building with insulated architectural precast concrete wall panels inset with terra cotta pieces. The panels not only provided protection and energy efficiency, but also created an aesthetically pleasing appearance.

The 172,000-square-foot building features a sweeping glass façade that curves around a landscaped public entry plaza and festival space. The concave glass curtain wall leans back as it rises, canting in one direction and then the other, sloping from one wing to the other. On one side, upper floors step back, with each level topped with a green roof.

"The combination of energy efficiency and ballistics protection in particular pointed us quickly to precast concrete," says Kevin Miller, president and principal in charge of the project at GSBS Architects. "We also needed a high-performance material that could withstand a 7.5-magnitude earthquake and allow immediate occupancy afterward." That seismic level is well above code requirements even in this stringent region, he notes. "The building serves first responders, and they needed to be ready to help immediately."

The ability of precast concrete to provide dense, thick walls offered the key to the needed ballistic protection, he notes. Designers wanted to ensure that officers were protected from drive-by shootings and other projectiles, with the building's durability intended to discourage them from being fired in the first place. Manufactured with 7,000-psi concrete, the panels consist of 1 $^{3}/_{16}$ inches of terra cotta, a 3 $^{1}/_{16}$-inch concrete wythe, 2 ½ inches of rigid polyisocyanurate insulation, and an interior 4-inch concrete wythe.

"That thickness of terra cotta and concrete provides a pretty good deterrent," Miller says. The panels were designed to protect against high-caliber ballistic penetration, and tests showed that no projectile ever penetrated to the second layer of concrete, much less through it.

The 9-foot-tall by 30-foot-long panels were connected to the columns of the steel structure. They were attached to allow the panels to move with the frame, which is braced with 55 viscous seismic dampers stacked on vertical columns. The panel sizes and weights created no special challenges in connecting them to the frame.

"Our goal was to ensure that the building moved smoothly with a seismic event, so the first responders

'Our goal was to ensure that the building moved smoothly with a seismic event.'

could get up off the floor after the structure stopped moving, dust themselves off, and get back to work," Miller says. The design's dampers only come into play with a truly massive seismic displacement, he adds. "It won't even notice smaller earthquakes. The fourth story will have a lot of energy to absorb, but the design was created to dampen that effect."

The thick panels also increase the energy efficiency of the building, providing an R-value of 19. Composite pin connectors tie together the concrete wythes, minimizing thermal bridging. Recycled rebar was used for reinforcement. Designers also intend for the concrete's thermal mass to aid with cooling needs, Miller says. "In the summer, the walls will store the cold air at night and help keep the building cool during the day."

Energy efficiency, as well as the use of recycled materials and minimizing construction waste, were key benefits that precast concrete helped provide. Once it is reviewed, the building is expected to achieve a LEED Platinum rating. The precast concrete panels also helped the LEED rating by being manufactured locally. Other key sustainable-design concepts included on-site rain gardens, saving existing mature trees; incorporating window louvers to direct sunlight, installing high-efficiency lighting, utilizing reflective roof materials, and using low-flow plumbing fixtures.

Aesthetic Design Enhanced

These functional needs were matched by the building's aesthetic design. The designers' goal was to complement the nearby historic city hall's Neo-Gothic design that featured brown sandstone. "The use of terra-cotta tiles embedded in the precast concrete panels allowed us to create a dialogue between the buildings despite the difference in age," Miller says.

The Old-World style of the sandstone's texture was achieved by mixing three colors of terra cotta in random patterns, creating a complementary shade to the sandstone that has a similar uneven appearance. "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."

The tiles were fired as 1- by 5-foot tiles, and they were embedded into the panels to create a 30-foot grid pattern. That long, narrow size fit into panels that were large enough to make the panelization economical without requiring special connections or design considerations to provide the necessary seismic movement.

"There were concerns that the budget wouldn't be able to accommodate terra cotta, at which point we would have tried a pigmented color for the precast concrete," Miller says. "But the design was standardized sufficiently to keep it economical."

Erecting the pieces posed only one usual difficulty, crane placement had to accommodate the existing mature trees to maintain that sustainable-design factor. Working in an older neighborhood with existing trees required close communication, but resulted in no delays. Large hoisting cranes were used that allowed the cranes to be positioned farther from the building and existing trees than would have been necessary with an open site.

Opened this summer, the public-safety building has met all of the owners' functional goals while providing an aesthetically strong civic meeting place. "The precaster did a really good job in bringing our vision to life," says Miller. "Where the various materials have to interface, the precast concrete is performing well. It was a challenge to match all of the tolerances we needed on these various materials, but they did it."

World War II Museum

The U.S. Freedom Pavilion (aka The Boeing Center) anchors the multibuilding World War II Museum campus in New Orleans, La. The facility, the second of four structures to be built from the master plan, stands tallest at 100 feet, allowing it to dramatically showcase a variety of airplanes and other artifacts from the period. The building features architectural precast concrete panels that were designed to provide a durable, strong appearance while adding storm protection and a long service life.

The building's construction follows the 2012 completion of The Theater Pavilion (aka the Solomon Victory Theater), the Stage Door Canteen and the American Sector restaurant. The Theater houses a 120-foot-wide screen for a 250-seat "4D" (including live action) theater. Both buildings—as well as the Campaigns Pavilion that is nearing completion—are clad with architectural precast concrete panels supplied by the same precaster.

"The precast concrete façade provided a number of features that made it a strong choice," says Bart

'The precast concrete façade provided a number of features that made it a strong choice.'

Voorsanger, principal at Voorsanger Architects PC. The firm won an international competition to design the master plan and architecture for

The latest addition to the World War II Museum campus in New Orleans, La., the U.S. Freedom Pavilion is the tallest of four structures. It features architectural precast concrete panels that provide a durable appearance while adding storm protection and a long service life. Precast concrete is being used on all of the facilities on the campus, parts of which are still under construction.

PROJECT SPOTLIGHT

U.S. Freedom Pavilion–The Boeing Center

Location: New Orleans, La.

Project Type: Museum

Size: 36,000 square feet

Cost: $21 million

Designer: Voorsanger Mathes LLC (a limited liability corporation comprising Voorsanger Architects Inc., New York, N.Y., and Mathes Brierre, New Orleans, La.)

Owner: The National World War II Museum, New Orleans, La.

Structural Engineer: Weidlinger Associates, New York, N.Y.

Contractor: Woodward Design+Build, New Orleans, La.

PCI-Certified Precaster: Gate Precast Co., Monroeville, Ala.

Precast Components: 253 architectural panels

the museum campus, anticipated to be completed in 2017. The design was divided into phases to ensure funding could be provided as it progressed, create attractive venues for selling naming rights, and allow the museum to adapt and grow as earned income rose.

The concept for all of the buildings' façades combines precast concrete with large expanses of glass and a metal-rib cladding. Each design features its own unique personality and geometry. The Freedom Pavilion features sloping façades consisting of a series of horizontal precast concrete panels created from repeating configurations of trapezoids and parallelograms. The panels are designed without a single 90-degree angle, and with horizontal joints aligned but tapering, and vertical joints running diagonally.

"Precast concrete's ability to be formed into different shapes, angles, and sizes made it the perfect choice for this museum," says Ed Mathes, chairman of Mathes Brierre, which aided in completing production documents and serving in the field. The two firms created a limited liability corporation, Voorsanger Mathes LLC, to serve as architect of record.

The architects' goal in designing the complex façade system was to create a "visually and inherently strong impression that could provide a light, vibrant environment, not a dark one," Voorsanger says. "Too often, war museums are dark and foreboding. We wanted to visually say that this inherently strong country conducted its efforts during the war to liberate and seek the peace."

Precast concrete was an efficient material for this project because the region has many capable precasters who understood the design concept and had no difficulty addressing fabrication challenges, Voorsanger says. "The bids were very competitive, which was important." The bidding process began shortly after Hurricane Katrina hit, which meant an economical design was vital to ensure construction could continue. "It was a difficult time to attract funds."

Value-Engineered Framing

Precast was also instrumental in helping the designers to value engineer the steel framing cost of the project. For instance, the metal framing system was value-engineered after the initial pavilion was completed. For it, vertical tubing was designed to create anchor points for the panels. Due to the variety of shapes and sloping sides, the anchors staggered a bit as they changed vertical position. "We ended up using more steel than we anticipated, and we had to clean that up," Priola explains.

Working with the precaster, the design was changed for the Freedom Pavilion to create horizontal tubing, which provided more uniform anchoring points, as the horizontal panel edges remained parallel. This also allowed the tops of lower panels to connect to the same anchor point as the bottom part of the upper panels. "This design made it easier and faster to connect the panels, which reduced material and labor costs," Priola explains. "As a result, despite the complicated panel shapes, the installation progressed without a problem."

The connections will withstand high winds that are common in the area, while the precast panels will protect the building from wind-borne debris due to their inherent strength and resiliency. The size of the panels reduces the number of joints and provides a long-lasting façade that requires little maintenance over its service life.

The precast was designed to replicate an as-cast appearance, which required extensive mold fabrication and a super-light pressure blasting with a special blasting media. Panels on the first level also were sealed with an anti-graffiti coating that allows paint and other markings to be erased easily. The museum's name also was cast into the panel on several façades to create dramatic signage that emphasized the building's strength and permanence.

The panels have a typical height of just under 8 feet. They feature skewed ends and legs, with about 23 panels longer than 40 feet and one longer than 50 feet. Due to the unusual patterns, one panel was 45 feet long and 2 feet tall. Panels on the building's edges also feature an 18-inch return to avoid joints on the edges. Casting the irregularly shaped legs in sequential order required a great deal of form shifting and close communication to ensure the proper panels were fabricated when needed. In some cases, full-size templates were printed to ensure the correct detailing.

The erection moved smoothly despite work continuing on the campus in other locations and continual visitor traffic to the already opened Victory Theater. "New Orleans can be a difficult environment for construction," Voorsanger says. "It's a quasi-tropical zone that's far different from northern climates. But the precast system was something everyone was comfortable with."

Work has now begun on the Campaigns Pavilion, adjacent to the Theater Pavilion, which will provide space for exhibits from the original museum. That phase will be followed by construction of the Liberation Pavilion, Special Exhibits Pavilion, parade ground, and Canopy of Peace. Those buildings also will be clad with precast concrete panels following the same design concept.

"We've been very pleased with the quality we received," says Voorsanger. "A surprising benefit was that everyone quickly understood the architectural concept and saw little difficulty producing it. When the contractor feels confident about providing the product you want and can erect it smoothly, they have less risk to account for and can bid more confidently."

> 'We've been very pleased with the quality we received.'

The museum already has proven successful with local citizens and visitors, with the second and third pavilions attracting more than 1 million visitors annually and garnering the largest membership of any private museum in the country. "It's been extraordinarily successful," Voorsanger says. "We're extremely pleased with how well it's been received."

Single-Family Residence

A number of residential designers and homeowners are learning the benefits that precast concrete can provide. Bensenville, Ill., resident Kim Olea can't say enough good things about her two-story, 2,000-square-foot home built with a high-performance precast concrete structural system and insulated wall panels.

The home was the first of what was to be a series of residences built by the DuPage Housing Authority to aid residents displaced by expansion at nearby O'Hare International Airport. Ultimately, budget cuts and other economic factors resulted in only one home being built. Olea purchased the home after she left her original home under eminent-domain procedures.

"I watched the cranes building the home, never expecting I'd be living there," she says. "I wasn't familiar with precast concrete, but it's a great house. I feel very safe in it. It's economical to run and environmentally friendly. It's been great."

> 'I wasn't familiar with precast concrete, but it's a great house. I feel very safe in it.'

The home features 8-inch-thick precast concrete insulated wall panels consisting of 3 inches of polyurethane insulation sandwiched between two 2 ½-inch-thick wythes of concrete. The insulation is bio-based, containing castor oil and soybean oil. The home was enclosed with 21 load-bearing panels, which support insulated precast floor panels to create the structural system.

The 10-inch-thick floor slabs consist of 4 inches of insulation sandwiched between two 3-inch-thick wythes of concrete. These panels also contain radiant-heating tubes that provide the home's heat. Electrical boxes and conduit were cast into the precast panels, as required by local code, and also into the floor panels per the architect's request.

The Housing Authority brought the concept of a total-precast concrete home to architect John Cronin, principal at Number Nine Design in Elmhurst, Ill. "Concrete was perceived as having a number of benefits, especially mitigating sound in this area around the airport, as well as providing durability and sustainability," he says. "The goal was to reduce long-term costs for the homeowners."

This residence in Bensenville, Ill., features a total-precast concrete structural system and insulated precast concrete panels. The home's traditional design belies its state-of-the-art features, such as radiant heating and a highly durable and sound-resistant shell that works well near O'Hare International Airport.

PROJECT SPOTLIGHT

Private Residence

Location: Bensonville, Ill.

Project Type: Residence

Size: 2,000 square feet

Cost: $300,000

Design-Build Team: Number Nine Design, Elmhurst, Ill.

Owner: Private homeowner

Contractor: Gene Orrico, Builder

PCI-Certified Precaster: Dukane Precast Inc., Naperville, Ill.

Precast Components: Twenty-one 8-inch-thick wall panels, twelve 10-inch-thick floor panels

Cronin visited the precaster and was impressed by the concept of sandwich wall panels. "It has a lot of potential but isn't well known for use in single-family residences," he says. "But it worked well with our design concept, which was to keep the home simple and modular while fitting it into a traditional residential neighborhood. Precast would lend itself to a contemporary design, but we weren't looking for that in this case."

The radiant-heating system, consisting of $^5/_8$-inch tubing placed one-foot on-center, will keep the home warm and energy efficient throughout its service life, he notes. "That was a key concern, along with making the home durable and safe." Each floor has its own thermostat, allowing the homeowner more control over energy usage.

The roof was framed out and shingled, and interior walls were framed and drywalled. "We did a lot of planning on the front end to ensure the home seemed traditional, planning the openings and other design details," says Cronin.

The 33 precast components were erected quickly in the four-bedroom home, providing quick protection from the elements and allowing interior trades fast access. "We maintained a traditional layout on a modest size to allow it to be replicated easily."

The homeowner has become a fan of precast concrete. "The radiant-floor heating is the best heat I've ever had in a home," she says. "And the precast concrete walls keep the heat inside very efficiently in the winter. In the summer, the concrete walls keep me nice and cool."

She appreciates the home's other benefits, too. "It's really soundproof, so the planes going overhead aren't a problem," she says. "And I have absolutely no worries about storms, wind, or hail that hit us every so often. I feel like I'm living in a bomb shelter. It's very sound and solid. I would highly recommend this construction to anyone looking for a home."

'I have absolutely no worries about storms, wind, or hail that hit us every so often.'

Citrus Warehouse

At the other end of the scale, designers and constructors of a $200-million, 640,000-square-foot citrus-packing facility in Delano, Calif., also found the resilient benefits offered by precast concrete components to meet the challenges they face. Its

An aggressive schedule and the need to meet strict hygienic standards led designers at this 640,000-square-foot citrus processing and packaging plant in Delano, Calif., to specify a structural precast concrete system including architectural panels.

high-performance precast concrete structural and envelope systems not only had to meet high seismic requirements and a fast schedule, but also had to provide for the needs of a busy transportation facility and food-processing plant.

The design-build firm, Younglove Construction LLC, had previously worked with the owner's representative, Eric Johnson of Paramount Citrus, on projects undertaken at another firm. Johnson told Younglove Senior Vice President Bill Bradbury to cost out several construction options, including precast concrete. "He likes using precast concrete for food-processing plants, because it provides a variety of advantages that save long-term costs," Bradbury says.

The durable, smooth panels create an ideal environment for sanitary food handling, as they offer no cracks or holes where dirt or moisture can lodge, as well as no way for vermin to gnaw their way in. They also provide long, open spans that make installing large, processing and packaging equipment easier. "A precast concrete interior is smooth, minimizes dust ledges, is easy to clean, and is durable," Bradbury explains. "It's not possible to create such an easily maintained interior with steel."

The designers provided cost estimates for both steel-frame and precast concrete structural systems. The precast concrete design was slightly more costly, but the owner chose it anyway, knowing the benefits it could provide. "He expects that small premium will be well worth it over the building's life through the other savings he will receive," says Bradbury.

Costs were minimized by bringing the precaster into the design process early, Johnson says. "Value-engineering and a partnership with the precaster helped reduce the cost of using precast concrete versus metal. It cost less than 10% more to use concrete, but food safety and longevity of the building increased substantially, which made it the obvious choice to invest in."

The structure features double tees measuring up to 80 feet long,

PROJECT SPOTLIGHT

Paramount Citrus Packing Co.

Location: Delano, Calif.

Project Type: Citrus warehouse and processing facility

Size: 640,000 square feet

Cost: $200 million

Designer/Contractor: Younglove Construction LLC, Sioux City, Iowa

Owner: Paramount Citrus, Delano, Calif.

Architect and Structural Engineer: Teter Architects & Engineers, Bakersfield and Fresno, Calif.

PCI-Certified Precaster: Midstate Precast, Corcoran, Calif.

Precast Components: 2,100 pieces, including double tees, columns, beams, solid walls, insulated walls, spandrels, plank, stairs, catwalk columns, catwalk beams, and wainscot

> 'Value-engineering and a partnership with the precaster helped reduce the cost of using precast concrete versus metal.'

columns, beams, planks, solid wall panels, and insulated wall panels. A precast concrete hybrid moment-frame system was designed to allow for the reduction in interior structural walls and to meet the high seismic needs in the region.

"An additional reason for specifying the precast concrete system was the aggressive schedule the owner required," says Bradbury. Precast concrete roof-tee construction began four months prior to the start of foundation work, once the column layout was finalized. A key concern was

> 'An additional reason for specifying the precast concrete system was the aggressive schedule the owner required.'

the need to use the 120,000-square-foot, fruit-conditioning rooms operation, where fruits are ripened. The company's facilities were filling quickly, so that portion of the building had to be completed first and fast.

To meet the schedule, the building was segmented into receiving canopies, conditioning rooms, sorting and packing, cold storage, support systems, and office space. Each space was self-sustaining with its own precast concrete structural system, explains Byron Dietrich, senior partner for structural engineering firm Teter Architects & Engineers. "We didn't build the building linearly or in the most efficient progression for construction needs but rather for the owner's needs in bringing portions of the building online first."

The cold-storage area was created with insulated precast concrete panels 12 feet wide and 40 feet tall. They included 4 ½ inches of rigid-foam insulation sandwiched between a 2 ½-inch exterior concrete wythe and an 8-inch structural concrete wythe and connected with fiber-composite ties. Prestressing strand was used in both the architectural and structural wythes of these panels to prevent cracking. The office portion features steel framing and a limited number of architectural precast concrete panels, due to the complexity of the office structure.

The building's high seismic requirements were met primarily with precast concrete walls and the precast concrete hybrid moment frame. A key challenge came from connecting the panels, due to their 40-foot height and relatively narrow width, Dietrich explains. Hold-downs were placed on every six panels to create expansion joints.

In addition, the building's 450-foot width had to be accommodated without using interior shear walls that would block equipment. Long-span diaphragms were used along the building's length in the direction of the double tees, while the moment frame provided the lateral-resistance in the longer direction. "The system worked well and was easy to construct," says Dietrich.

Providing the number of entry doors for trucks to access the building also posed a challenge, as the entries had to be fit into the building's face with panels arranged to allow for as many openings as possible. "The facility's layout dictated the size and spacing of many of the openings," Dietrich says. Most of the openings were designed to be 13 feet wide and 16 feet tall, with about 3 feet of space between them.

A precast concrete mezzanine and elevated walkway system were added inside the 32-foot-tall building at the 16-foot level. They were constructed with horizontal arms that support planks, with the walls serving as shear and lateral support. "It's a beautiful, simple design," says Bradbury. "The seismic design included the mezzanine, and it makes a great way to not only oversee work in the processing areas but allow people to get to their work stations safely above the forklift traffic."

Roof-level double tees were supported on Cazaly hangers, which replaced corbels that could have retained dust. The hangers are cast into the tees and sit above the roof tee flanges, avoiding the need for lower corbels with dust ledges. "Precast concrete provided a lot cleaner design and works very well for food-processing operations," says Bradbury.

The design created an efficient, cost-effective, and rapidly constructed project. "It was a good project from a team perspective," Bradbury says. "Everyone pitched in to help resolve issues as soon as they arose."

Such an approach ensures that high-performance precast concrete

> 'Precast concrete provided a lot cleaner design and works very well for food-processing operations.'

maximizes its benefits for a project. As designs become more complex with owners' needs for faster construction, higher safety, aesthetic appeal and other factors, the precaster's input can help ensure that projects remain on time, in budget, and offer a long service life.

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Team Leader

HGA's Blanski thrives on building team consensus to resolve complex challenges

— Craig A. Shutt

Bill Blanski, AIA, LEED AP

Marquette University's 115,000-square-foot College of Engineering building consolidates four engineering departments and includes lab space, offices, classrooms, and other needs. The building, which achieved LEED Silver certification, features architectural precast concrete panels embedded with half bricks and accented with cast-in, limestone-colored lintels and headers. All photos: HGA.

As owner demands and budget restrictions grow, projects become more complex and challenges become more daunting. Some architects find such trends frustrating and obstructive. HGA's Bill Blanski thrives on those projects and enjoys leading a team to overcome the obstacles.

"What I like best is working in a group as a community to resolve issues on complex projects," says Blanski, AIA, LEED AP, a vice president and design partner in the Minneapolis office of HGA Architects & Engineers. "I find I do better work in a team setting—and other people do better work too when I lead the group to find solutions. It's part of my DNA." That role has led him to thrive on such complex projects as university laboratories, multipurpose institutional buildings, and government structures requiring high sustainability and detailed specifications.

"Variety is important to a design firm," says Blanski. "There is a tendency to specialize in one type of work, but diversity helps create new ideas that can be used in other markets. Owners are always looking for new things, and are responsive to new ideas, materials, and approaches. We have a lot of sharing across offices." HGA operates seven offices around the country.

Three Philosophies

His goal as design principal, he says, is to "lead the design team to a shared understanding of the project on both a macro and micro level that will uniquely inform the design process." To do that, he uses three distinct design philosophies.

The first is an Iterative Design Philosophy, which progresses as more information is learned about the client's goals and the building's function. "We don't come in with just one approach. Our goal is to solve the problems as presented and move forward to a final solution step by step."

The second is the Contextual Philosophy. "I immerse myself deeply in the macro and micro activities of the building and the site to learn its details. We need to understand the nature of the site and its relationship to the work that will be done there." That process often takes months, he notes, and it continues through the preprogramming and schematic-drawing phases. "That gives us several months to research both the natural and human ecology."

The third, which he deems most important, is the Mission and Vision Philosophy. "We have to understand what ultimately drives our clients and get into the heads of the users, to learn what they need, what they want to accomplish, and how they can work best."

Blanski's path to architecture was ordained from an early age, he says. "I lucked out, because I always knew I wanted to be an architect, from the time I was in grade school." His certainty grew thanks to a high-school program that placed students in local offices to gain experience. He worked in an office, helping with design documents. He went on to earn a bachelor's degree in architecture from the University of Minnesota and a master's degree from Yale University.

After graduating, he worked at Buchanan Associate Architects in New Haven, Conn., for a couple years before settling in at HGA. After seven years there, he decided to open his own office in 1995—but returned to HGA in 1997.

"I had a nagging itch to run my own office, and I had a very successful time," he relates. "But I realized I like a big office and working in a community. I knew I'd have to spend 10 or 15 years building my practice to work on the same complex projects I could be working on that very minute at HGA. So I decided to return."

The type of complex projects he enjoys can be seen in his design for the College of Engineering at Marquette University in Milwaukee, Wis. The 115,000-square-foot building, designed in collaboration with Opus, consolidates four engineering departments and facilitates interaction among them. It was clad with architectural precast concrete panels embedded with half bricks and accented with precast concrete limestone-colored lintels and headers.

"That was a fantastic project for my skills, because some of our clients were structural engineers. They could appreciate the materials being used." Blanski often uses natural materials from the Minnesota area, embedding them into precast concrete panels. "Precast concrete's benefits often resolve problems with its speed of erection, efficiency in enclosing a building, and integrating stone or brick while creating a panelized system. Owners are looking for buildings that will last but also will be low in maintenance."

Today's Complex Projects

Today, he's leading the design of a $250-million, corporate-headquarters project that involves 35 people, not including the contractor's team. "Leading this group and being part of the discussions as we work through issues is what I enjoy about being a design architect."

New challenges continue to arise that must be resolved, he notes. "There's a profound interest, with the economy still recovering, to find value wherever possible and stretch dollars further. Along with that is an increased focus on sustainability and being a better steward of natural resources, conserving energy, and reducing our carbon footprint. Those goals don't have to cost more. It's exhilarating and inspiring to find solutions to meet each need."

Over the years, Blanski's collaborative skills have extended to include serving as an adjunct assistant professor at the University of Minnesota's College of Design. "Teaching has always been a passion of mine. I'm committed to helping to educate and bring in the next generation of architects."

Those efforts have been reduced in recent years as he focuses more on design work, but he has compensated by leading church-sponsored groups during the past 12 years to build service facilities in Guatemala. His group of 50, which spends 10 days in the country, has built computer schools and homes, and installed water-filtration systems. They use local materials, design the structures, and partner with local trades. The group has included his three children, who now are all married.

That work will provide grist for the mill as he prepares for tomorrow's challenges. "I'm excited about the new ideas being developed for the tenor of design in office environments," he says. "There is a significant overlay of efficiency and flexibility that needs to be balanced."

The inspiration for the color palette for this GSA building in Portland, Ore., was the Pacific Northwest and its giant redwoods and sequoias. The precast concrete architectural wall panels feature punched windows in only three sizes to simplify casting. It includes a system of western-cedar patterned, vertical blades applied over the panels to act as sunscreens and reinforce the natural patterns in the landscape. Fine black sand was added to the mix and a light sandblast was applied to achieve the dark

Thanks to technology, today's employees can work anywhere, for good and bad, he notes. "We have to find ways to ensure their environment encourages creativity as they roam, whether it's in a communal work space or the coffee shop. I have a passion for finding ways to create work environments that Millennials who are geared to computer mobility and life/work balance can use to maximize their efficiency."

The 176,000-square-foot collocation laboratory for the Minnesota Departments of Agriculture and Health creates collaboration space, as well as clean rooms, laboratories, and office space. The building was clad in architectural precast concrete panels inset with local limestone, which was integrated to conceal panel joints.

Wilmette, IL

Completed in 1953, the Baha'i House of Worship showcases the intricate details that can be achieved with precast concrete.

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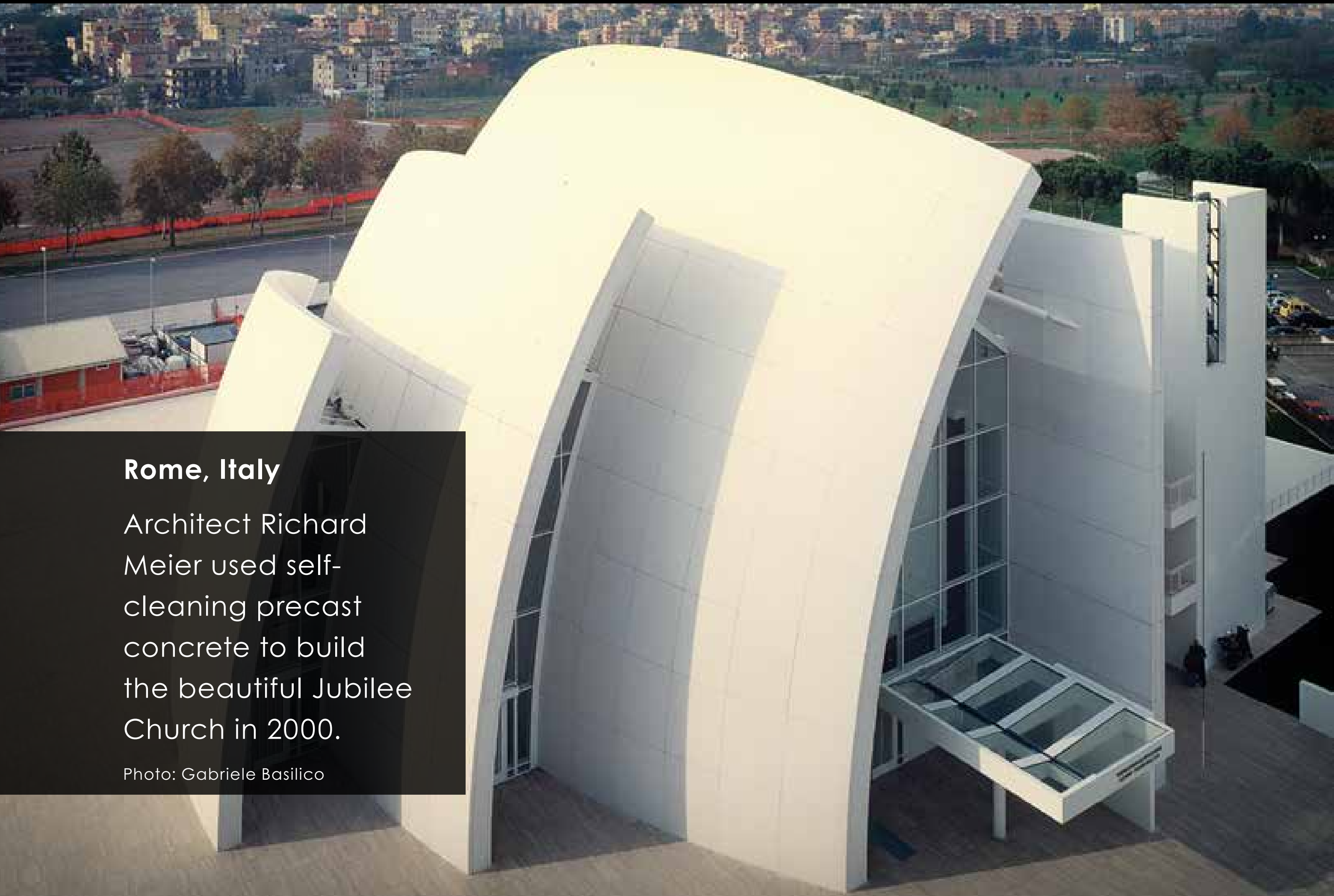
WHAT DO THESE BUILDINGS HAVE IN COMMON?



Rome, Italy

Architect Richard Meier used self-cleaning precast concrete to build the beautiful Jubilee Church in 2000.

Photo: Gabriele Basilico

Record-Breaking Courthouse

Dramatic precast concrete façade design not only creates distinctive appearance and provides high blast and energy performance, but sets record for fastest ever delivery

— Craig A. Shutt

With design and construction completed in only 27 months, the James F. Battin United States Courthouse in Billings, Mont., set the record for the fastest delivery of a federal courthouse in modern history. Architectural precast concrete panels were used to help express a dramatic visual appearance while also achieving strict standards for Anti-Terrorist/ Force Protection (AT/FP) needs and energy efficiency. More impressive still: the construction processes used on the Battin Courthouse also can be replicated for future projects to reduce costs and improve performance.

"Precast concrete provided attributes that were important to meeting the security and blast requirements that we needed," says Marvin Doster, project director at M.A. Mortenson Co., the design-builder. "Once we began examining it, we realized it also could provide a dramatic aesthetic design and help achieve our energy-performance goals as well."

The facility is located in downtown Billings and houses three courtrooms, four judges' chambers, the U.S. Marshal Service, and other court-related federal officers. The building features four distinct architectural elements that delineate each of the building's functions.

The first design concept was to make "Justice Visible." To achieve this, courtrooms were placed on an upper level with large expanses of glass and smooth precast concrete cladding. "Federalism" was represented by a precast concrete colonnade and classical portico, which bisects the main structure and stands over it.

"High Performance" was attained via the colonnade, the architectural precast concrete panels, and

The James F. Battin United States Courthouse in Billings, Mont., features four distinct architectural elements: "visible" courtrooms with soaring windows on top, a precast concrete colonnade and portico, a base clad with architectural precast concrete panels textured to represent a solid, stone foundation, and the use of local materials throughout. All photos: Sean Airyart.

other energy-efficient applications. "Regionalism" was embodied in the rusticated precast concrete base, directly recalling the geology of the surrounding Yellowstone rimrocks. The three-story base contains offices that visually and symbolically support the smooth precast and glass courtroom floors above.

"These concepts were not considered in isolation," says Steve McConnell, managing partner at NBBJ, the architectural firm. "Rather, they are woven into one integrated, contemporary design with key features simultaneously addressing all four concepts."

Blast Resistance Required

As a federal courthouse, the building had to meet a Federal Threat Level 4 design standard. "This threat level proscribed specific engineering-performance requirements for the exterior systems," Doster explains. "We also had a variety of other factors to consider that had to work with that requirement. The precaster's engineering staff was able to create a mix design, thickness, reinforcing pattern, and connection design for the panels that met all of the performance needs in an economical manner."

The balance of attributes required to meet AT/FP restrictions can create challenges for structural engineers and precasters. For most projects, wind loads are the controlling factor, which typically require panels to be stiffer, with more reinforcement to increase the load capabilities. Blast protection requires panels that are stiff enough to be durable but ductile enough to absorb a blast force. Blast protection also requires connections that hold the panels securely while providing a systematic path for progressive collapse.

The blast engineer and precaster created the ideal blend of characteristics using 3D modeling and engineering programs in a give-and-take relationship. "Blast-protection designs are more complicated from engineering and reinforcing standpoints," explains Chuck Smith, vice president of operations at Gage Brothers Concrete Products, the precaster for the project. "Finding

The stone texture on the courthouse's base was created by using 12 formliners combined in different ways, including flipping them 180 degrees, to create larger panels. The panels were erected in a particular sequence to avoid repetition. Each liner had a different skew, creating as much as 4 inches of offset between any two panels.

PROJECT SPOTLIGHT

James F. Battin United States Federal Courthouse

Location: Billings, Mont.

Project Type: Courthouse

Size: 147,000 square feet

Cost: $59 million

Designer: NBBJ, Seattle, Wash.

Owner: General Services Administration, Rocky Mountain Region, Denver, Colo.

Structural Engineer: Magnusson Klemencic Associates, Seattle, Wash.

Blast Engineer: Weidlinger Associates, New York, N.Y.

Design-Build Contractor: M.A. Mortenson Construction Co., Bellevue, Wash.

PCI-Certified Precaster: Gage Brothers Concrete Products, Sioux Falls, S.D.

Precast Speciality Engineer: Gage Bros and Infrastructure LLC, Omaha, Neb.

Precast Blast Consultant: Protection Engineering Consultants, San Antonio, Tex.

Precast Components: 349 architectural panels and column covers the correct amount of reinforcing to balance all of the needs was the key."

The panels needed to be ductile enough to bend but not break when hit by large forces, adds Collin Moriarty, engineering manager at Gage. "Instincts say to add more reinforcement for protection, but that makes the panels stiffer, which attracts more load from the blast back to the building. The goal is to spread the blast force over the panels and direct into the connections, then allow them to fail at points designed to contain the force. That ensures the energy dissipation is controlled."

For the courthouse, this design required a number of large plates and oversized bolts. To achieve the right combination of stiffness and ductility, Moriarty created panel designs with specific combinations of reinforcement and connection locations and sent them to Gage's blast consultant, Protection Engineering Consultants, who responded with dynamic load calculations.

'We had to determine the best balance of reinforcement and connections.'

"We had to determine the best balance of reinforcement and connections," Moriarty says. "They would send back the calculations, and I would adjust the design to bring the loads into alignment with what we needed, then send those back to see how they worked."

Each location had specific needs. The upper level courthouse walls, for instance, had to interface with large expanses of glass. Seven inches thick and eccentrically hung, with 18-inch returns, they presented stiff sections that produced serviceability concerns along with blast needs.

"The stiffness of these corners produced ridiculously large loads in the dynamic analysis," he says. Dynamic blast analysis produced a middle tieback load that was "off the charts." After discussions with the blast engineer, the panels were tied back and designed for blast at the top and bottom, while the center connection was designed for a wind load. "That arrangement made it more flexible so it met all of our requirements."

Energy Performance Enhanced

The panels also were designed to meet high energy-performance requirements, keeping the building on track to be certified LEED Gold. The courthouse was designed to be at least 30% more energy efficient than the industry standard, with initial energy savings reaching more than 40%, McConnell says. High-performance strategies were incorporated through the design, including active beams for heating, cooling, ventilating, and water-saving techniques. Recycled materials, local manufacturing, and minimal construction waste also were emphasized, and the precast concrete materials aided each of these goals.

The precast concrete panels also were a key part of the super-insulated exterior wall system, which also includes triple-glazed windows and shading from the colonnade for the west lobbies. "We used the high thermal mass of the precast concrete to help our energy performance

To create the elaborate textured appearance for the lower levels, designers added a 2-inch face to the front of the panels that served as the aesthetic design, giving them depth to replicate the stone patterns they desired.

In some areas on the first level, recessed façades required the precast concrete panels to be set first so steel could be erected over them. Close cooperation on such issues allowed the project to be completed in a record-setting 27 months.

and added insulation to the interior side," Doster explains. That face was textured to allow a spray-foam insulation to adhere readily. Structural support and framing members were designed and set at intervals that allowed access to the complete precast concrete panel to ensure consistent insulation coverage.

Unique Aesthetic Design

Along with meeting these strict functional needs, aesthetically expres-sing the four key design concepts was a key goal. The courthouse's programmatic layout lent itself to emphasizing each section in a distinct way. This was most apparent with the lower floors, where formliners were used to create a varied and textured appearance in the precast concrete panels.

"The solid-appearing lower three floors, housing offices that program-matically support the justice system, form the rimrock base for the 'visible justice' of the courtrooms above," explains McConnell. "The concrete patterning of the lower three floors is therefore designed to appear somewhat random, with carved angular planes for the strong local sunshine to play upon."

Achieving this apparent random-ness took considerable planning. "We looked at several concepts, but we ultimately simplified the concept by essentially adding 2 inches onto the face of the panels to use for our aesthetic design," explains Doster. "We were able to accomplish every-thing we wanted to achieve with the precast concrete, which was important. We could focus the façade with one supplier, which really helped the budget."

The architect created the design plan for the textures, which the precaster calculated would require 18 formliner designs. The two teams then used BIM technologies to tweak the design to reduce that total to a dozen basic patterns that were combined in various permutations to produce eight large panels, which were then erected in a carefully orchestrated sequence. Each liner had a different skew, so between any two panels, up to 4 inches of offset could occur.

'We could focus the façade with one supplier, which really helped the budget.'

The precaster changed the liner position with each panel to vary the look and avoid repetition. "There is a pattern if you look really hard over a large enough area, but we don't think anyone can pick it out," says Smith. "We spent a lot of time with the architect finding the best solution that provided a strong aesthetic appearance that also was the most economical."

Two color variations were achieved by changing only the sand ratio in the mix, which provided a golden tone and a purer white. Both received an acid-etched finish. "The goal was to create a 'Yellowstone' color as well as a 'traditional government white' color to offer contrast," says Doster. "Combined with the various geometric shapes, it creates a variety of distinctive but complementary sections."

"The challenge of creating two contrasting but complementary colors and textures was creatively solved by the design-build team," says McConnell. "Mock-ups of several variations of sand, aggregate, and colorant mixes, with varied levels of finish, were produced and shipped to the site. There, we reviewed them in relation to each other, to the adjacent materials, and to the site."

BIM Aids Design

BIM design software was used extensively throughout the project, he notes. "This enabled the design team to see the finished façade in different lighting conditions prior to making a single piece of precast concrete. Using local knowledge, sands, aggregates, and colorants, we could ensure we produced panels that reinforced the relationship of the courthouse to its native surroundings."

Joints were kept consistent with the use of a blown-sand technique. While the caulk was still wet, a low-pressure hose blew in sand particles, which adhered to the caulk and helped minimize the appearance of the joint. "It improved aesthetics and created an organic appearance," McConnell notes.

A key to the courthouse's success was hiring the precaster on a design-assist basis early in the process, says Doster. "By selecting them early, they were able to provide practical solutions for design and

A key to the court-house's success was hiring the precaster on a design-assist basis early in the process.

construction challenges as they arose without any delays."

The precaster's early involvement also helped speed up construction, a primary goal for the government. Several areas posed particular challenges that required adapting the typical schedule to ensure fast construction. For instance, the first level's entry area features recessed façades behind the tall colonnades. These areas had to be erected first so steel could be erected above them. This sequencing requirement meant these first-level panels had to be cast first while minimizing change-overs.

To speed up the process, the design team, contractor, and precaster coordinated pre-welded connection platforms in a tight gap between the slab-closure plate and the back of the panels. The connections in this area also had to meet blast requirements, necessitating additional calculations for the connection forces. "The use of BIM as a planning and scheduling tool assured the entire erection was a very well-coordinated process," says Doster.

The large triple-pane glass inset into the blast-resistant precast concrete walls on the upper levels also required design coordination, although more due to placement challenges than connection needs, Smith notes. "The glass and concrete areas were designed simultaneously to ensure the loading requirements for the two materials together had been met."

Initially, contractors expected to lower the windows into place from the top, but the complicated framing and tall, narrow size of the massive windows made that difficult. Instead, the erectors slid the windows in from the open sides of the structure.

Panels were delivered to a staging area off-site and brought to the site and erected by one crane, which had to work around power lines located along one side of the property. The deliveries remained on track, despite flooding on some roads between the site and the precaster's plant in Sioux Falls, S.D., requiring trucks to navigate around road closures and through detours. Even with these difficulties, all pieces arrived as scheduled and were erected as planned.

Two color variations were created for the precast concrete panels by changing the sand ratio in the mix. That change created a golden "Yellowstone" color as well as an offsetting "traditional government white."

Design Aids Future Projects

The coordinated efforts of the design and construction teams led to completion of the courthouse in only 27 months. Best of all, it was the second of three designed using a new process by the federal government intended to speed up construction on future projects. Funded by the American Recovery and Reinvestment Act, the projects are the first in the General Services Administration's (GSA) new Design/Build/Design Excellence process, which combines a fixed price with a design competition. The first courthouse, located in Bakersfield, Calif., was completed in 30 months.

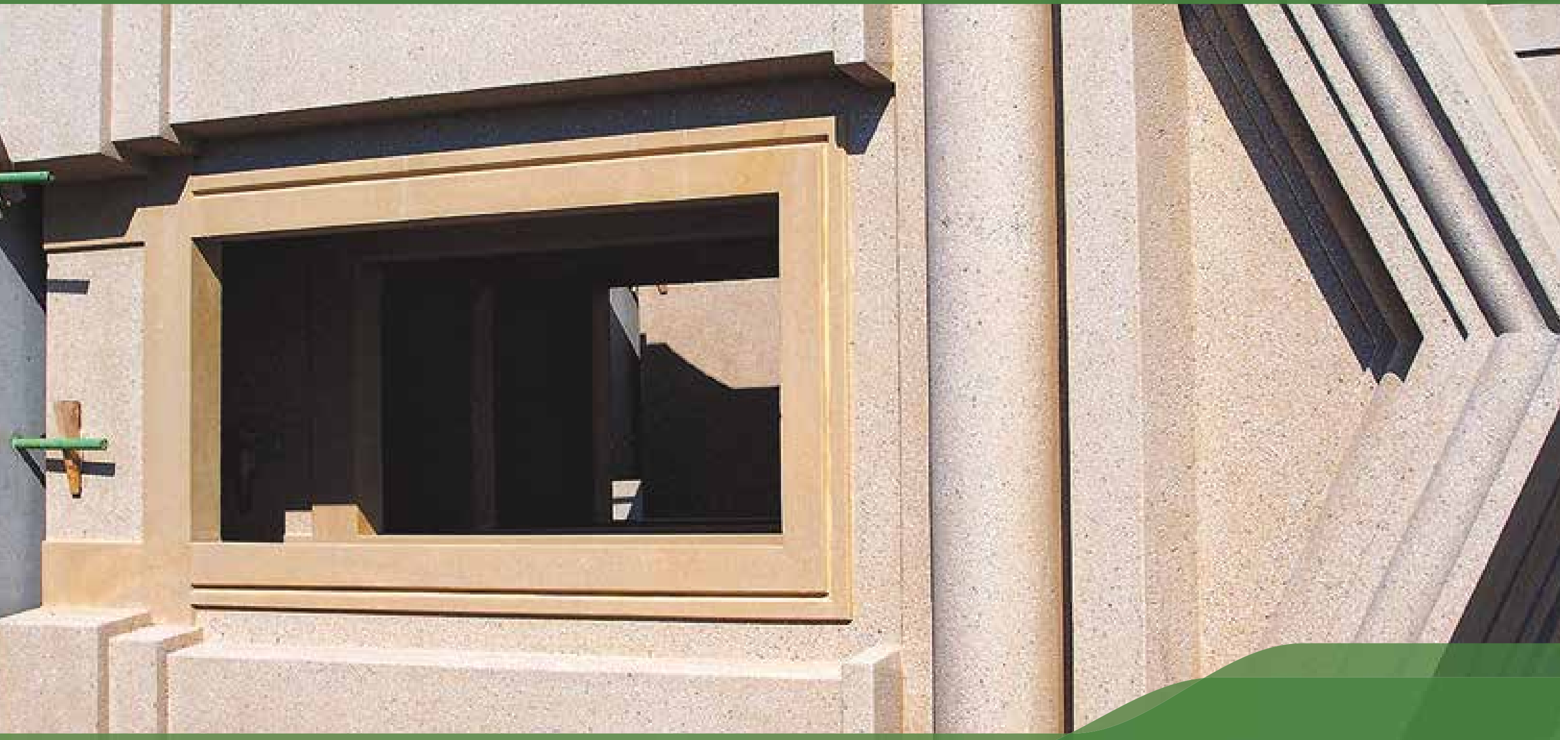
"This approach to fast construction can be replicated," says Doster. "It requires GSA to have all funding for the project upfront so there are no delays moving from design to construction." Often, GSA's funding is paid out in increments, creating lags as funds are approved, causing the design process to slow and costs estimates to rise on materials.

It also requires that the project team use the design-build process, a delivery process that ensures each member of the design and construction team provides input early. "GSA is committing to the design-build process more often. For us, bringing in the precaster on a design-assist basis early made a big difference." Designers also must continue to take advantage of the growing array of high-tech design tools now available, including BIM and lean processes, he says.

Despite the intricacy of the courthouse's design, the project's speed can be replicated in the future using the same procedures by GSA, which ensured no delays in funding as the project moved from design to construction.

McConnell agrees that the process works. "By ramping up our use of building-information modeling, working closely with subcontractors to align design intent with budget during the early concept phase, and increasing the collaboration between GSA, design, engineering, and construction partners, we've taken a significant step toward modernizing the nation's infrastructure."

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



Total Building Commissioning

Building commissioning provides owners and designers increased assurance that buildings will perform as expected

— by James T. Morrissey, Michael Amstadt, and Rita Seraderian, PE, FPCI, LEED AP

Building commissioning is quickly becoming a key component in green codes and standards, and a requirement of owners who are concerned that their high-performance buildings perform as designed. High-performance design principles have gained traction in the design community and among owners for their ability to enhance the service life of facilities and reduce life-cycle costs. There is an increased recognition of the importance of ensuring that building systems, glazing, and superstructure are delivering on the designer's assumptions.

– James T. Morrissey is a regional director for Building Commissioning Services Inc. He has over 30 years experience in the building construction industry and an is active member of the AABC Commissioning Group.

– Michael Amstadt, is a regional director for Commissioning Agents Inc. He has over 21 years experience in the fields of start-up, maintenance, commissioning and qualification and is an active member of ASHRAE Guideline 0 and Standard 202 Committees.

– Rita L. Seraderian, PE, FPCI, LEED AP has been the executive director of the Precast/Prestressed Concrete Institute Northeast for the past 22 years. She has organized, hosted and spoke at numerous seminars and workshops on the use of precast/prestressed concrete products and systems throughout New England and New York. She provides design assistance on all aspects of precast concrete construction.

The U.S. Environmental Protection Agency (EPA) defines the importance of building commissioning to them: "In many ways, commissioning is similar to a 'test run' or 'systems check.' It tests, verifies, and fine-tunes the performance of key building systems so that the highest levels of performance are achieved. Correctly implemented, commissioning is extremely cost-effective, and should improve the building delivery process, increase systems reliability, improve energy performance, ensure good indoor environmental quality, and improve operation and maintenance of the facility."[1]

One critical aspect of the commissioning process is the need to begin it during schematic design. Early involvement of the commissioning agent aids the design professional in developing the Owner's Project Requirements (OPR), the subsequent design team Basis of Design (BOD) and the beginning of the Operations & Maintenance (O&M) Systems Manual. These tools are vital elements in the commissioning process, and if their development is delayed until the construction documents (CD) phase, the commissioning process may have to be modified to fit the design, resulting in the loss of performance improvement critiques during CD development, and a reduced ability to effectively track system quality after construction.

The basic goals of building commissioning are best defined in the Whole Building Design Guide (WBDG), a website developed by the National Institute of Building Sciences:

According to WBDG, the goals of commissioning are to:[2]

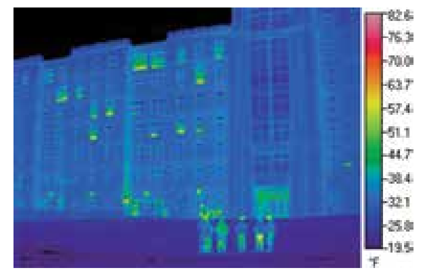
1. Define and document requirements clearly at the outset of each phase and update through the process;
2. Verify and document compliance at each completion level;
3. Establish and document commissioning process tasks for subsequent phase delivery team members;
4. Deliver buildings and construction projects that meet the owner's needs, at the time of completion;
5. Verify that operation and maintenance personnel and occupants are properly trained; and
6. Maintain facility performance across its life cycle.

The Commissioning Authority (CxA) can be contracted by anyone of the stakeholders, such as the owner, facilities manager, design team, construction manager, or even the contractor. The commissioning services can include new construction or renovations. Even existing facilities can be scoped for fundamental, enhanced, or total building commissioning. Guidelines for the commissioning process can be specified by American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), National Environmental Balancing Bureau (NEBB), the Building Commissioning Association (BCA), or a selection of many other organizations.

Commissioning and LEED

As for LEED®, fundamental commissioning is a base requirement, and therefore does not add any points to the total required for certification. The minimum requirements of systems

Catholic University's Opus Hall utilized precast concrete sandwich wall panels to create their thermally efficient envelope.



Thermal imaging shows that the precast concrete walls have no thermal bridging. All Photos: Little.

to be commissioned only include energy-consuming components of the mechanical systems HVAC, lighting controls, and domestic hot water systems. Enhanced commissioning provides three points toward LEED certification and consists of fundamental commissioning with the design phase and warranty phase tacked on to the commissioning scope. The design phase commissioning work includes two design reviews, at 60% and 95% completion of construction documents, and either preparing or reviewing the design professional's commissioning specifications. Reviewing the OPR and BOD is also required. The warranty phase includes facilities personnel training, review of systems manuals, an 11-month inspection after occupancy, and possibly seasonal testing.

There is much more to commissioning. It is important to make sure everything that operates within a building, and protects it from damage, protects its occupants from harm, is designed and installed properly, and works as intended. Some additional systems or components which should be considered for commissioning include: power distribution, emergency power, life safety, communications, domestic water supply, fire suppression, conveying systems, and the building envelope. With manufacturing, healthcare, and laboratory facilities, additional systems and equipment might also include clean steam, medical gasses, laboratory gasses, purified water, fume hoods, isolation rooms, incinerators, and process equipment. This is called Total Building Commissioning (TBC).

Envelope Commissioning

A number of factors are leading owners, designers, and construction professionals to adopt building envelope commissioning. These factors include: the growing complexity of building envelope design, increasing numbers of different construction materials, shrinking schedules, increasingly stringent performance demands, and the need to construct energy-efficient buildings. Building envelope commissioning is a means to ensure that the building envelope is constructed to meet the design intent, expected service life, and code requirements, as well as to aid in the prevention of complications that otherwise might arise during the construction process. It involves a number of different components, such as opaque walls, roof, windows, curtain walls, foundation, caulking, acoustics, air, vapor, moisture, and thermal barriers. There needs to be communication starting at the design development phase, to establish the owner's performance requirement for each component. During the design phase, the commissioning agent reviews the design and specifications to confirm that all pieces are included and all trade scopes are clearly and fully defined. During the construction phase, submittals are reviewed for conformity with the design documents and installations are inspected periodically to confirm adherence with the design and approved submittals, as well as standard construction practices.

The testing phase involves prescribed test procedures to verify the envelope's ability to meet the design requirements related to water penetration, thermal resistance, humidity, and air barrier requirements. These tests typically include timed roof flooding, water pressure applications, building pressurization, and infrared thermography—all of which should be written into the specifications and witnessed by the commissioning agent. In some cases, commissioning may continue beyond project completion. Envelope commissioning will then be able to facilitate and ensure that the required communication, coordination, testing, verification, and documentation results in the delivery of a building envelope that performs as specified, as designed, and within budget.

As for testing, the most effective tool used in the commissioning process is the infrared camera. With a building pressurized and a sufficient temperature differential, infrared thermography (IRT) can detect opening in the buildings enclosure and thermal bridges. Wet sub-materials, such as roof insulation or masonry back-up, can also be detected with IRT, indicating leaks in the superstructure.

Air barrier testing is now required for all new federal buildings with an allowable air leakage of 0.25 CFM per SF of building surface at 75 pa (30" wc). Once the building construction is completed, the testing team is scheduled for a nighttime operation. The general contractor seals all designed openings (door jambs, dryer vents, etc.) with tape. The building is pressurized with mobile fans incrementally up to the 75 pa limit. Differential pressure readings are a taken across a door opening. With the data collected and the building surface area provided, the air leakage rate can be calculated. This is normally done with a software package. During pressurization, IRT is performed on the outside of the building, including the roof. The process is then reversed for depressurization with the data recorded in similar manner. The IRT is performed on the inside of the building as well.

In many cases, however, commissioning is not considered until a project reaches the construction phase. While still valuable, implementing commissioning after construction begins will be less effective than comprehensive commissioning, which starts at the predesign phase, because there is less opportunity to organize and plan ahead.

The objectives of the building envelope-commissioning process are driven by building type, expected life cycles, geographic location, climatic considerations, desired energy efficiency, budgetary constraints, and tolerance for leakage, all of which may vary considerably among projects. While the commissioning goals and benefits are common, the precise tasks comprising the commissioning process will differ from project to project.

One of the best performing envelope systems in this test are precast concrete panels, due to their low permeability, continuous insulation, and thermal mass. Like any exterior wall system, however, the design professional must take care to carefully detail flashing and sealant joints, and utilize the commissioning agent to confirm that they are installed properly. The advantage of precast concrete sandwich walls over other systems, such as glass curtain walls or metal panels, is that precast envelopes require far fewer joints than these other systems. While IRT testing does not address the integrity of the vapor barrier or thermal barrier, the integrity of these systems can be measured with temperature and humidity mapping while the building HVAC is providing climate control.

Building envelope commissioning is a rapidly growing AEC project management practice because of its benefits. Commissioning of the building envelope helps to ensure that all of the building systems are working properly and efficiently, protected from undesirable outside elements, and that indoor environment is maintained as intended.

1. U.S. Environmental Protection Agency (EPA), "Commissioning." Last modified July 07, 2012. Accessed July 11, 2013. http://www.epa.gov/iaq/schooldesign/commissioning.html.
2. National Institute of Building Sciences, "Building Commissioning." Last modified June 11, 2012. Accessed July 11, 2013. http://www.wbdg.org/project/buildingcomm.php.

To learn more about building commissioning, design professionals and owners may want to access these resources:

1. General Services Administration (GSA) Building Commissioning Guide: http://www.wbdg.org/ccb/GSAMAN/buildingcommissioningguide.pdf http://www.gsa.gov/portal/category/21064
2. The Whole Building Design Guide (WBDG) Building Commissioning section: http://www.wbdg.org/project/buildingcomm.php

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

Commissioning Standards

The Commissioning Industry is being driven by several organizations, each with their own guidelines and standards. Several of the key players in this process are ASHRAE's Guideline 0-2005, NEBB's Procedural Standards for Whole Building Systems Commissioning, BCA's New Construction Building Commissioning Best Practices, LEED® and the National Institute of Building Sciences (NIBS) Guideline 3-2012, Building Enclosure Commissioning Process. Most commissioning documents either reference ASHRAE Guideline 0-2005 or roughly align with it. This also aligns with the LEED® certification program since LEED® v2009 for both Fundamental Cx (EAp1) and Enhanced Cx (EAc3) reference ASHRAE Guideline 0-2005. Also to standardize the commissioning process, ASHRAE is in the final stages in the development of Standard 202 – Commissioning Process for Building and Systems, which defines the minimum efforts to meet the needs of commissioning. With Standard 202 providing minimum requirements, Guideline 0-2005 is the best practice document for defining building commissioning.

Formliner Artistry

Architects and precasters are using cutting-edge technology to expand the artistic capabilities of formliners to feature textures, embedded materials, and photo realism

— Craig A. Shutt

CAD-CAM technology was used to manufacture the master molds for the photo-engraved rose images used on the precast concrete panels cladding the Cleveland Medical Mart & Convention Center. Photo: Architectural Polymers.

Formliners have been used for decades to provide creative finish details for precast concrete. Today, however, new techniques and technologies are allowing a wider array of designs at lower costs. But to maximize success, the design team should be in close communication with the precaster early in the design process.

"The technology of formliners has progressed tremendously," says Marshall Walters, president of Architectural Polymers Inc. "In the past, some architects avoided formliners because they couldn't get the design they envisioned. Now, it's possible to achieve most designs if the designer and precaster communicate well about it."

Shane Calmes, owner of Advanced Formliners, agrees. "Architects are really challenging us to create intricate designs. They're thinking outside of the box, and we're creating new custom designs that bring their vision to life."

One of the most dramatic enhancements has come from the growth of Computer Numerical Control (CNC) routers, which use computer programs to precision cut patterns, shapes, or even photos into formliners. But intricate molds, expanded texture options, embedment capabilities, and creative layouts are also providing new techniques that architects can use to meet owner needs and produce a dramatic, arresting aesthetic statement.

Using a few designs that repeat in nonlinear ways can reduce costs while creating an attractive design, such as in this design by artist Vicki Scuri of Siteworks. Photo: A.L. Patterson.

Textures

The range of textures has expanded as new forming capabilities have allowed formliner producers and precasters to provide more detail and configure forms to minimize the appearance of repetition. Reuse of formliners creates a significant cost savings, but architects often want to change forms to avoid creating a panelized appearance. In many cases, textures are created to hide joints and eliminate repeating highlights that stand out.

A new technique called "puzzle-piecing" uses each texture as a module and fits them together in different ways within each panel, explains Buck Scott, president of Scott System Inc. "The goal is to shift the textured liner 90 degrees or turn it so that it looks entirely different in the next panel."

This technique is also used to maximize the impact of shadow lines, he notes. Designs can be cut so that when they are seen from one direction, the images are deep and dramatic, while they can't be seen at all when viewed from the other direction.

In many cases, the textures appear more realistic because they are made from formliners produced from molds of actual stone or other materials. Often natural stone can be used to make custom molds.

The new techniques are attracting designers' attention. "Rock textures are big, and they're not going away." Says Jim Bohrer, vice president of Custom Rock Formliners. "They provide a timeless design for any type of building, soundwall, or mechanically stabilized earth (MSE) wall."

Attaching veneered stones to panels also is gaining in popularity. Formliners are often used to hold natural stone in place during the precast manufacturing process while the concrete is being cast. Most recently, terra cotta was embedded into structural precast concrete panels to clad the CONRAC (Consolidated Rental Car Facility) at Logan International Airport in Boston, Mass. It was the first such use in North America and one of the few in the world. (For more on this project and other veneered-stone applications, see the Spring issue.)

'Rock textures are big, and they're not going away.'

Another new technique has created a granite-like concrete appearance that sparkles when reflected by sunlight. Using either black or white aggregate creates distinctive, eye-catching designs that replicate the appearance of quartz, says Calmes. Three or four color shades can also be created with only one aggregate through different finishing techniques.

Thin Brick

Bricks have been inset into concrete panels since 1971, when an elastomeric formliner with pockets to hold brick pavers was used for a high-rise residence in Denver. The range of brick options has grown as more designers utilize this high-performance method of constructing a brick wall. The ½-inch-thick to ¾-inch-thick thin bricks are precision engineered to fit into molded forms that offer a variety of faux brick joint configurations. The joints never require repointing, since they are formed from the body of the 6000 psi concrete panel.

"There are new players supplying brick, because precast panels embedded with thin brick have

Formliners and forming techniques can be used to create intricate patterns of buildings such as this church in Dallas, Tx. Photos: Gate Precast

This photographic reproduction was created using a CNC router on a panel with white cement and black aggregate. Photo: Gate Precast.

grown in popularity," explains Mike Denson, sales manager for Innovative Brick Systems LLC. "More brick companies are supplying thin bricks." Bricks with an aged appearance are growing popular to provide a historic appearance or to match existing buildings in the neighborhood."

The designs are becoming more complicated, he notes, including herringbone patterns, soldier or vertical courses, and arches with keystones. "Designers are looking for more detail and trying to hide joints or the panelized design by adding more visual interest."

Bricks used in formliners must maintain tolerances outlined in PCI's *Standard for Thin Brick*, stresses Mark Porreca, sales manager for architectural finishes at A.L. Patterson. "ASTM tolerance standards aren't tight enough. With so many layers of bricks being stacked, being off slightly means the last rows must be cut off or adjusted in the field. Tight tolerances when placing bricks into molds is critical."

Designs and Lettering

Lettering and more intricate designs, even artwork, can be impressed into precast concrete panels, using molds created from the original artwork, lettering, or logos. These are particularly popular for institutional and governmental buildings to provide a solid, chiseled appearance.

The key to designing these pieces is to ensure appropriate draft or taper for stripping the pieces from the forms. Recessed letters should have right-angle shoulders and a flat back to stand out, according to PCI's *Architectural Precast Concrete Manual*.

Often, more elaborate designs are crafted as clay pieces from which the molds are made. In some cases, CNC routers are used to cut foam pieces to the proper shape. This can be less expensive, but it doesn't leave room for error, notes Scott. "If you don't like the clay design, you can change it before you make the molds. You can't do that with a routered design."

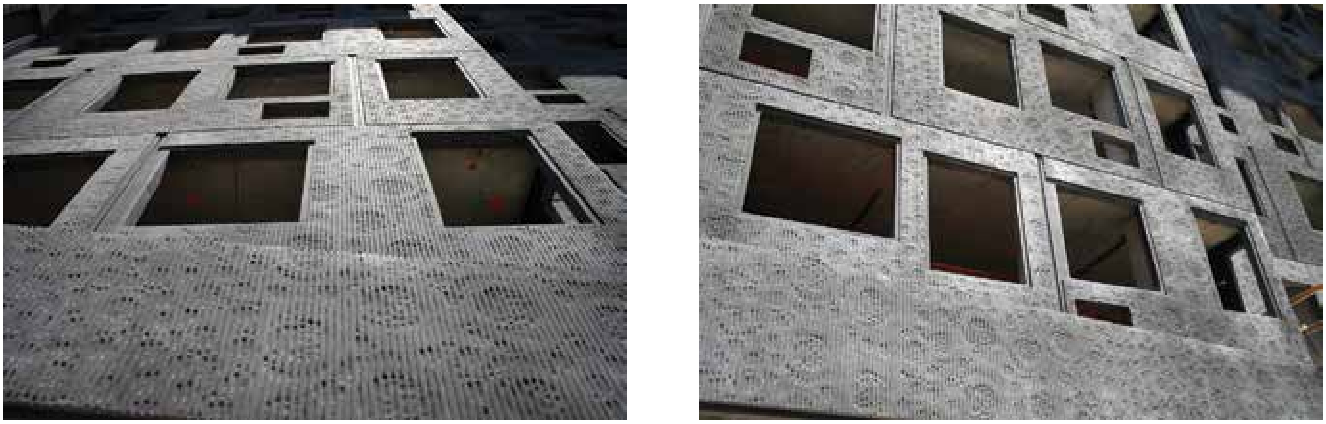
Scenery Options

Elaborate designs, intended to evoke natural scenes including fauna and flora, are being created more often. Soundwalls and MSEs in particular offer long, unbroken canvases on which to produce creative scenes. "More highway departments are getting involved and hiring artists to create images," says Walters. CNC routers work well for these options, he notes, because the artist can provide his drawings and see the resulting three-dimensional image. "A CAD rendering speeds up the process by allowing the artist's work to be approved and manufactured in a predictable time frame and accurate manner."

> 'A CNC router with five-axis capability allows a high degree of detail.'

"A CNC router with five-axis capability allows a high degree of detail," says Porreca. "But turning a two-dimensional image or drawing into a three-dimensional piece to be cut into the liner can consume a lot of time as depths are defined and interpreted. Providing a three-dimensional file early in the process assures that all parties know what is required and eliminates assumptions that can be costly."

These designs can be hundreds of feet long and up to 30 feet high,



CNC routers are being used to create patterns and grayscale designs by cutting to precise lines and cutting deeper to create a darker tone. Photos: Architectural Polymers.

Combining color and forms in a puzzle-piecing type of application can create attractive designs that work well on long surfaces such as soundwalls. This design, which changes every five panels, was created for a Las Vegas soundwall using Rocky Mountain flagstone with bands of purple Oregon Basalt texture, puzzle-piecing the two textures for a continuous pattern along its face. Photo: Scott System.

combining molds and moving from panel to panel. The designs can become quite intricate. "I can put a quarter onto a 5-foot by 5-foot panel and read all the markings on it," says Scott. "Concrete provides great reproduction." In some cases, designers are specifying high-flowing, self-consolidating concrete (SCC) to provide greater detail and a smoother finish.

Photographic Designs

CNC routers also are being used to replicate photographic images. These are accomplished by programming the image into the router and having it cut vertical lines through the concrete, cutting deeper to produce darker lines. "It's a trick of the eye, and not that expensive," says Walters. "For highway soundwalls, it's a great idea—they have large expanses and a lot of eyes looking at them."

Designers are taking advantage of these capabilities to produce creative images. "Anything can be translated, particularly if we receive a CAD drawing, and more designs are being created today with CAD-CAM or BIM programs," Walters notes. "The routers are very accurate. The only concern is creating ridges so thin that they break off during stripping or handling."

Graphic Concrete

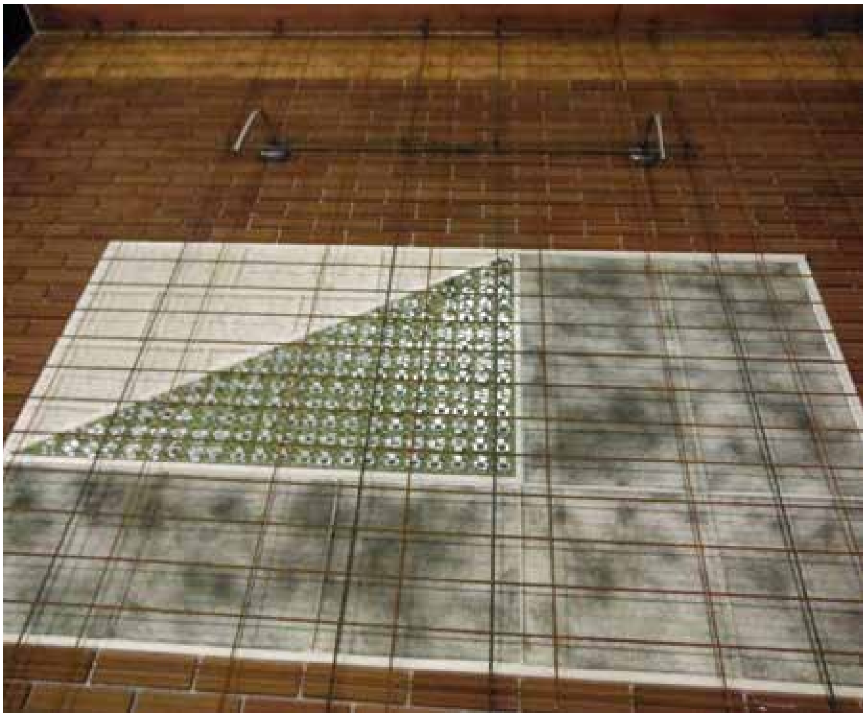
A new process, graphic concrete, allows designers to use obtain unique concrete surfaces. The technology is based on applying a surface retarder to a special membrane that is placed over the mold. The designed pattern or picture is created by the contrast between the fairface and the exposed aggregate finish. The images may be existing patterns, repetitive patterns created by designer, or photographic images. The images created by exposing the aggregate may be viewed from any angle.

Considerations

Creating custom formliners that accurately reproduce the designer's vision can be a complex process. Involving the precaster early in the design phase, so he can work with the formliner manufacturer, will ensure schedules are maintained and problems are resolved early in the process. Some considerations include:

Scheduling: Brick can require six to eight weeks to manufacture, and mock-ups or prototypes often are created prior to final design approval. Selecting brick early so formliners can be created to their exact dimensions is critical. "These issues need to be addressed early to ensure there is time to order materials and create the forms and retain the schedule," says Porreca. Brick manufacturers often fire brick in a rotation going from lighter colors to dark, so the order must be placed early enough so it will be produced and shipped on schedule.

Repetition: Designers often want to avoid a repetitious, panelized appearance to what is planned as a natural, flowing façade. Adjusting patterns to turn them or otherwise break up the repetition can create



This design features inset thin brick and tile in several patterns to create a dramatic appearance. Photo: Advanced Formliners.

that appearance at a low cost. Using formliners for many pours helps reduce costs.

Casting Schedule: Efficiencies are created if repeating forms can be used to cast the largest pieces first, then cut down to cast smaller pieces, Porreca says. Having time in the schedule to allow pieces to be cast out of erection sequence and staged will minimize the number of liners and the ensuing cost.

Cost Factors: A wide range of factors impact the cost of a formliner, including material used, detail of the design, changes made after the original design, and size. For instance, increasing a shallow recess to several inches in depth can increase costs significantly due to the amount of material needed to create that depth. Larger molds also become more expensive as they grow in size due to shipping and handling costs—but the larger size may reduce the number of molds needed, reducing costs. "We have a number of tricks we can use to help reduce costs," Walters says. The main trick is to begin working with a precaster or formliner as early as possible.

Material Choices: Urethane liners are often more expensive than other types, but they are designed for reuse, and their durability allows more repetitions, which cuts the cost per mold. But urethane liners require proper panel-production sequencing, built-up material on casting beds or rails, as well as enough panel production to warrant the initial square-foot cost, says Calmes.

"In current building trends, we're seeing architects mix up building façades so they lend themselves to a single-use type formliner, which can be cut inexpensively and quickly to match the custom-panel design," he notes. "They eliminate the intricate production-panel sequencing that can slow erection schedules, saving the precaster—and the project—both time and money."

There are even semiclear polystyrene formliners that allow the designs to be seen through the formliner as they are cast. "They make it easy to see how the design has been placed in the casting bed," says Calmes.

The range of designs that can be created with formliners today ensures that virtually any vision created by the designer can be accomplished. Early input by the precaster can help ensure that the result matches the intent and that it is created an inexpensively as possible. A

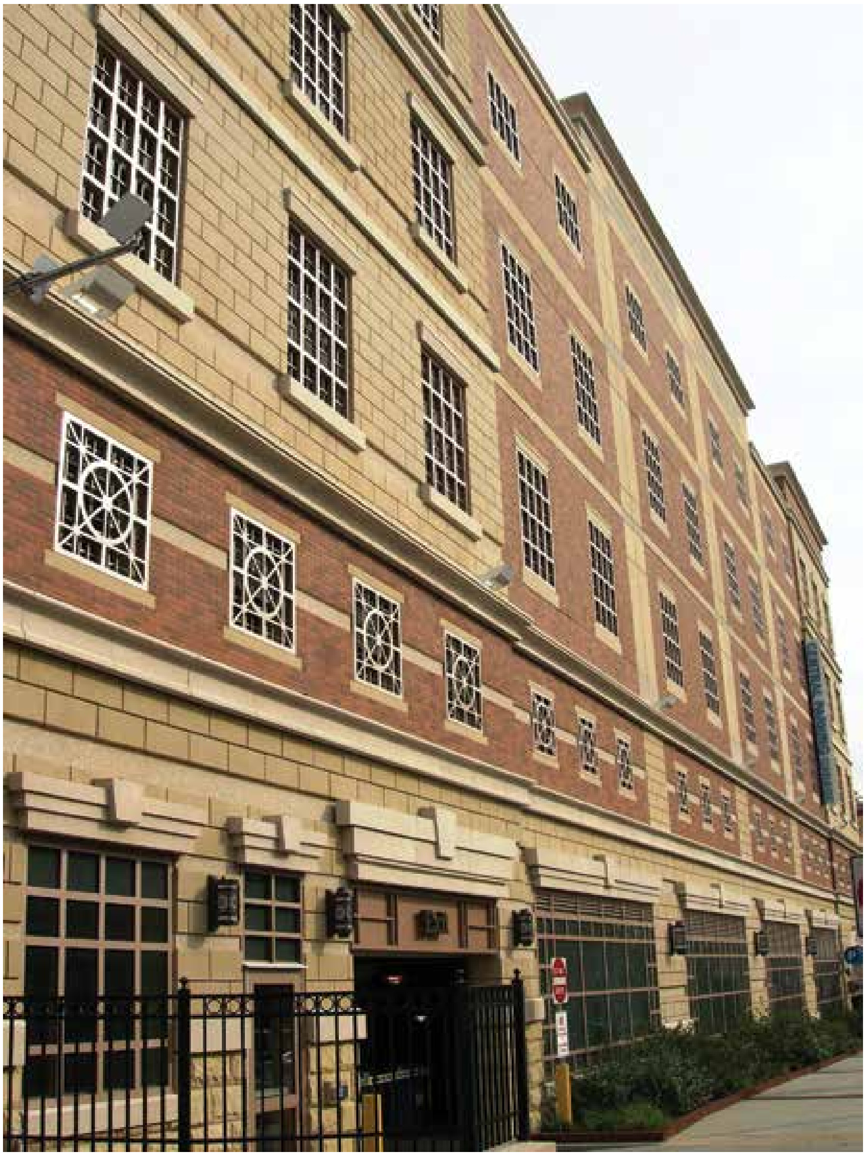
For more information on these or other

Soundwalls provide long, flat canvases for images. Some states imprint their panels with state birds, flowers, and other personalized images. This swallow mural was created on soundwalls along Route 5 in San Juan Capistrano, Calif. The birds were sculpted from foam and cast into multiple large urethane formliner parts. Photo: Custom Rock Formliners.

projects, visit www.pci.org/ascent.

Textures with significant depth create shadow lines and add aesthetic value to buildings. Photo: Advanced Formliners.

Puzzle-piecing is a technique in which one form is used to cast a number of panels, but the design is turned 90 or 180 degrees to create a less repetitious pattern. This design was used on a highway ramp in Shoreline, Wash., with designs by Vicki Scuri of Siteworks. Photo: Scott System.



Architects are becoming more creative in combining textures, shapes, and designs to create distinct aesthetic treatments in precast concrete panels. These panels with embedded thin brick using Scott Brick Snap Systems are featured on the parking structure for Lancaster Newspaper in Lancaster, Pa. Photo: A.L. Patterson.

Bridge designers are incorporating formliner designs into their structures, especially in highly visible locations. This design on a bridge in Nashville ties into the railroad yard that the bridge spans. Photo: Scott System.

This three-piece soundwall design, called Thunderstorm over the Mesa, splits into clouds, diagonal striations, and foundation pieces for easy installation of a complex image. The design was created by Sites Southwest in Albuquerque, N.Mex. Photo: Scott System.

So real you would not know...Seamless!

No brick or block was used for this building only Solocast™ imprint formliners

Testimonial by precaster for the above project:

"Dukane Precast continues to be impressed with Advanced Formliners' ability to respond to the critical time schedules that our client's often demand. This project required several formliner appearances and Advanced Formliners went the extra mile to fabricate and deliver their fine products in record time to keep the project on pace for this important client. We have received many compliments on the stunning appearance of this building and we are proud to work with Advanced Formliners to produce beautiful structures such as this one."

- Brian Bock , Dukane Precast

We also advanced the art of embedding bricks

Precast bed photo courtesy of: Wells Concrete Products
Solocast 1000 Caulkless Corner Accessories (patent pending)

PCI Continuing Education

PCI is a registered continuing education provider with the American Institute of Architects (AIA), and the National Council of Examiners of Engineers and Surveyors (NCEES). PCI also has registered programs with the Green Building Certification Institute (GBCI). PCI's educational offerings include a variety of programs to fit your schedule and preferred learning environment, such as webinars, seminars, lunch-and-learns, and online education. To learn more, visit www.pci.org/education.

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Upcoming Webinars:

- **Back to the Future: Relearning Passive Fire Resistant Design**
  August 27 and 29
- **Artist's Palette: The Aesthetic Versatility of Precast Concrete**
  October 22 and 24
- **The New Sound of IEQ: Indoor Comfort and Acoustic Design**
  November 19 and 21

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 new resource at www.pci.org/elearning.

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PCI and its regional affiliates offer seminars all over the United States on a variety of topics. Visit www.pci.org/education for up-to-date seminar listings, additional information, and registration.

Upcoming Seminars:

- **Quality Control Schools**

  Level I/II
  October 23–25, Chicago, Ill.
  November 4–6, Calgary, Alberta, Canada
  December 9–11, Nashville, Tenn.

  Level I–III
  November 4–9, Calgary, Alberta, Canada
  December 9–14, Nashville, Tenn.

  Level III
  October 22–25, Chicago, Ill.
  November 6–9, Calgary, Alberta, Canada
  December 11–14, Nashville, Tenn.
- **CFA/IES**
  December 9–11, Nashville, Tenn.
- **CCA**
  May 22, 2014, Nashville, Tenn.

Lunch-and-Learns

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.

Durability, Continued Performance Makes Precast a Common Choice

Radisson Blu MOA. ©Hanson Structural Precast 2013

Resiliency is a key attribute of high-performance structures. It can be measured in how well the structure stands up to natural and man-made forces and how well it resists and rebounds from such disasters as earthquakes, fire, blast, and high winds.

Stated another way, high-performance structures must be durable and must demonstrate high performance over time. They make use of building materials and systems that integrate and optimize attributes that provide long-term performance and durability.

Thanks to their inherent strength, engineering, and resiliency, precast components and building systems from Hanson Structural Precast meet these requirements. Hanson products and systems can be utilized to meet a variety of building types and sizes, design demands, and construction challenges, and continue to perform long term.

Proof that a building material performs well over time becomes apparent when regional building owners and designers continually choose the material based on the continued success and performance of existing, nearby structures.

As an example, look at the Mall of America (MOA) in Bloomington, Minn. Built over a 20-year span, a half dozen major precast concrete projects by Hanson Structural Precast surround this landmark development. Opened in 1992, the MOA can only be described as superlative with more than 4.2 million square feet, 520 stores, 25 rides and attractions in an indoor park, 40 million visitors annually, and one of the top tourist attractions in the country. It still ranks

28th Avenue Park & Ride. ©Hanson Structural Precast 2013

as the nation's largest retail and entertainment complex.

Hanson precast projects are on all four sides of this enormous structure:

MOA East/West Parking Ramp

Part of the original MOA construction, two massive parking structures flank the east and west side of the mall. The nearly identical, seven-story parking ramps contain a total of 12,550 parking spaces. The total precast ramps utilized precast double tees, spandrels, columns, beams, wall panels, and stairs from Hanson Structural Precast. "At the time, this was the largest precast contract ever signed in the United States," said Gary Pooley, sales manager for Hanson's Midwest Region. "The deck was so large that it had specified snow dump areas within the footprint of the buildings. It was the biggest project we had ever done."

Courtyard Hotel

Built just to the southeast of the MOA in two phases in the mid-1990s, the seven-story Courtyard Minneapolis Bloomington by Marriott contains 203 rooms and 2,800 square feet of meeting space. The building features Hanson precast columns, beams, hollow-core plank for the floors and roof, and interior 8-inch-solid, precast demising walls. Precast 30-foot planks span the building. Three hotel rooms fit in each bay.

IKEA Parking Deck

In 2004, Hanson provided precast columns, beams, double tees, and spandrels, for the 110,000-square-foot, elevated parking deck adjoining the new IKEA Twin Cities store across the street on the northwest corner of the mall. The single level deck, with parking on the roof, contains 320 parking stalls and provides an open stairway to on-grade asphalt parking. Hanson also provided precast components for a one-story deck for delivery truck on the opposite side of the store.

28th Avenue Park & Ride

A light rail line to downtown Minneapolis runs to the east of the MOA. In 2008, Hanson architectural precast cladding was utilized for a new five-level, 1,450, space cast-in-place parking ramp as part of the rail system. The precast cladding features an acid-etched, sand-blast finish. "We felt precast was the appropriate cladding for the building," says Greg Finstad, PE, senior professional engineer for project architect Short Elliott Hendrickson Inc., with nearby offices in Minnetonka, Minn. "We looked at what would be the best product for the aesthetics we wanted. Precast was cost competitive and attractive."

Radisson Blu MOA

Directly connected via skyway to the MOA at the mall's south side, is the brand new Radisson Blu hotel. Completed in March of this year, the 500-room, 16-story building is covered with Hanson precast architectural cladding. Both acid-etched and sandblasted precast panels in two primary colors and with an interesting reveal pattern are used on the hotel. In addition to the aesthetics, the locally produced, precast cladding adds to the project's sustainability with recycled reinforcement and fly ash replacement of cement in the structural portion of the panels. The horizontal, 6-inch-deep wall panels run floor-to-floor, and stretch 27-feet from column to column. The precast cladding was a major factor in the project's fast building schedule, according to architect Troy Fountain, AIA, of ESG Architects, Minneapolis.

Phase II of the MOA, to be built adjacent to the IKEA store to the north of the original mall, is scheduled to break ground in the last quarter of 2013. This development will include another luxury hotel, retail, dining, and a 545-space underground parking ramp. It's likely there will be more local precast concrete success stories in the future.

"We're proud to continue to help build up this major commercial area in Minneapolis," said Hanson's Pooley. "Surrounding building owners, their architects and engineers, keep coming back to us because our structures have lasted, handled everything that has come along, and have continued to perform. We pass the test of time." A

PCI Precast/Prestressed Concrete Institute

AIA CONTINUING EDUCATION

Weathering

PCI designer'snotebook

WEATHERING

A primary consideration in the architectural design of buildings should be weathering, that is, how the appearance changes as a result of exposure to atmospheric and environmental conditions. The action of weathering may enhance or detract from the visual appearance of a building, or may have only a slight effect. The final measure of weathering's effect is the degree to which it changes the original building appearance and distorts the designer's original design concept.

Visual changes occur when dirt or air pollutants combine with wind and rain to interact with the wall materials. The run-off water may become unevenly concentrated because of façade geometry and details. The manner in which water is shed off the structure depends primarily on the sectional profiles of the vertical and horizontal discontinuities designed into the wall.

Through the years, designers controlled the water flow down specific parts of a structure with copings, drip grooves, gargoyles, window sills, and plinth details. However, many of these useful and relevant details have been discarded as superfluous decoration.

For architectural precast concrete (as well as all other building materials), the awareness of weathering should be reflected in the design of wall elements and the integration of windows to control water sheeting and penetration and to manage water run-off. Staining that occurs through differential surface absorption and uneven concentrations of dirt due to water run-off are considered the most common weathering problems.

Many of the effects of weathering can be predicted by studying local conditions and/or existing buildings in the area. This will often give a clear indication of the levels of pollution; the velocity, principal direction and frequency of wind; and the intensity, duration, and frequency of rainfall, together with records of temperatures and relative humidity. All these factors will affect the way exposed concrete will get wet and dry out. With proper attention to the causes and effects of weathering, potentially detrimental results can be eliminated or at least minimized. Design tools for control of weathering are the massing and detailing of the building and the color, texture, and quality of the surface finishes. Precast concrete will become dirty when exposed to the atmosphere, just like any other material. Fortunately, with architectural precast concrete, the designer can choose shapes, textures, and details to counteract many of the negative effects of weathering. Although regular cleaning of a building may make detailing a less critical factor, maintenance costs should be balanced against initial design costs.

One of the major contributing factors to the weathering of precast concrete is dirt in the atmosphere. Atmospheric dirt or air pollutants include smoke or other gases, liquid droplets, grit, ash, soot, organic tars, and dust. Gaseous pollutants include SO_2, NO_X, H_2S, NH_3, and O_3. Sulphur dioxide (SO_2) can react with the lime in the concrete and the oxygen from the air to form gypsum. Gypsum's solubility allows for it to be washed away, taking dirt with it. Where there is insufficient water to wash it away it can encapsulate dirt and hold it.

The concentration of SO_2 and other corrosive compounds is high in some urban environments. When dissolved in rainwater, SO_2 produces dilute sulfurous or sulfuric acid. These acids etch cement-rich paste and carbonated precast concrete surfaces, showing more fine aggregate which may appear as a color change unless the fine aggregate and matrix colors are similar.

Fig. 1 shows the pH of acid deposition falling in the United States. during 2011. Although acid deposition (acid rain) is technically defined as precipitation with a pH level below 5.6, some researchers believe that it should be defined as low as 5.1. Using either definition, acid deposition has a far-reaching impact on both the United States and Canada.

In areas with unusually high concentrations of corrosive elements (pH of rainwater lower than 5.1), the designer should detail the façade for water run-off, specify concrete strengths and durabilities normally associated with architectural precast concrete, provide the required cover over reinforcement, avoid soft aggregates such as limestone and marble, and suggest more frequent washings of the building.

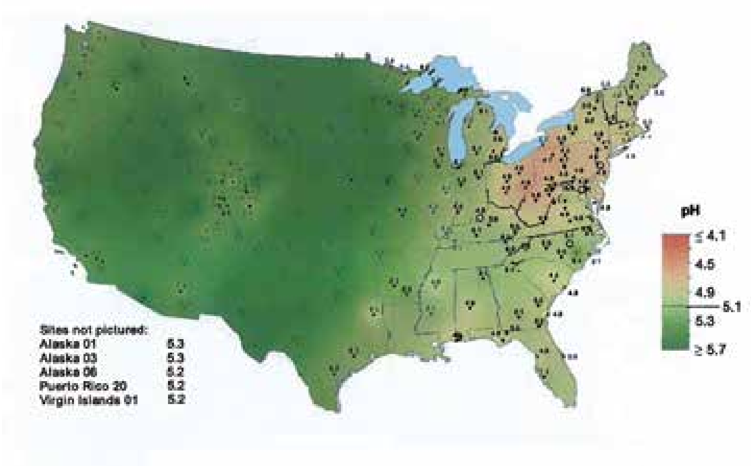

Figure 1 Hydrogen ion concentration as pH – distribution of acid rain.

The flow of rainwater across the building's façade has a profound affect on weathering patterns because rain run-off redistributes particulate matter that has been deposited fairly uniformly on the external wall surfaces. This deposit takes place more rapidly on surfaces facing upward and also on surfaces with a coarse texture. The designer should attempt to anticipate and plan for water flow over the wall, tracing water flow to the final drainage point or to ground level, particularly where discontinuities exist. When run-off reaches a discontinuity the water may bead and drip free. This may increase or decrease the run-off concentration, affecting both the run-off's ability to carry suspended dirt particles, and the subsequent drying behavior of the wall. Such changes of flow concentration may disfigure the building surfaces.

Usually rain run-off acts as a cleansing agent for the top of the building. However, at some stage the water will also pick up particulate matter already deposited on the walls and it becomes a soiling agent. The preferred lines of water flow must be arranged through shaping of surfaces and textures so that, at the point where water is expected to become a soiling agent, it will not detract from the finishes or forms of the building elements. Particulate matter will drop out of the run-off water when water flow velocity is decreased; for example, when the run-off is allowed to fan out. It may be necessary to have frequent details to throw water clear of the building, collect the water, or spread the water uniformly across sloped surfaces. Such details should be continuous to prevent differential rainwashing, or must terminate at bold vertical features, or maintain a clear distinction between washed and soiled areas. These differences can then, if required, be emphasized by the use of varying surface finishes.

The migration of run-off water is affected by:

1. The location and concentration of rain deposits.

2. The properties of water in contact with materials, especially surface tension.

3. The forces of wind and gravity.

4. The geometry, absorption, and texture of the building surface.

5. Drips.

The amount of rainwater, and the velocity and angle at which it falls is markedly different on each side of a building and at different heights. Therefore, it is not reasonable to expect equal weathering of all parts of the building. The influence of tall or massive buildings, projections, courts, or passages on prevailing winds can cause wind eddies to upset the natural flow of air and rain. This makes the effect of rainwater very difficult to predict. Also, a wall that receives a great deal of sunlight will dry out a lot faster and will be less likely to attract airborne particles.

The wettest portion of a building is typically the top corners of the windward face, followed by the top and side edges. The side wall, which is parallel to the wind direction, remains relatively dry. A wide face remains drier overall, particularly in its center region, relative to a narrow face. The taller the building and the higher the wind velocity, the relatively narrower the band of high rain impact. Increased wind speed also appears to cause greater wetting in the center of a façade. Corners may be subjected to 20 to 30 times more rain impact as compared with the central region of the building face.

Peaked roofs, cornices, or horizontal projections can substantially reduce the amount of rain that falls on a façade by reducing lateral acceleration at the wall-roof intersection. Horizontal projections that project 12 in. (300 mm) or more away from the plane of the main façade throw water off the building. These projections must have a drip on the underside to prevent water running back across the soffit. This stops soffit staining, and also prevents random staining on the surface below.

During storms, driving rain can come from any direction, but the quantity of water available on a façade for washing is normally determined by its relationship to the prevailing wind and the intensity of rain from that direction. Wind movements around buildings are affected not only by major climatic factors but by local topography, adjacent buildings, and groups of trees. All these will affect the amount and position of driving rain hitting a building and the way water runs down the façade. The drops of driving rain are guided for the most part by the air currents around the building and external wall components. The pattern of these air currents is independent of building height. Small obstacles give rise to sudden changes in direction of the air current and the raindrops cannot follow these sudden changes. The mass forces carry them forward to the obstacle. On one- or two-story buildings, the driving rain reaches the lower parts of the walls. Dirt stain patterns do not usually occur on such low buildings.

Air currents against buildings taller than a couple of stories are, on the other hand, deflected so gently that the air has time to re-orient the raindrops. When the wind blows at a building, some of the air will rise to pass at an increased velocity over the top; the rest will form a horizontal vortex and spiral away around the ends (**Fig. 2**). Less than half the quantity of rain that should pass through a free air cross-section of the same size as the building is caught by an external wall. This applies regardless of the wind force. The rain mainly strikes the top parts of the wall. Only edge sections (corners) are reached by the driving rain and in the central sections the raindrops move almost completely parallel to the wall. As a result, water run-off very seldom reaches all the way down to the ground, except at corner areas and projecting components, unless the duration of the rain is quite long. Therefore, special care should be taken to ensure that water is not allowed to run down surfaces unless there is enough water to wash the surfaces completely. When the runoff water reaches the area of wall that is protected from driven rain by the horizontal vortex it will be absorbed into the surface causing a typical zigzag dirt line. The level at which the jagged line of dirt forms will be governed by a combination of the height of the vortex and the absorbency of the precast concrete. The height of the vortex above the ground is determined by the height of adjacent buildings or other obstructions over which the wind has passed. A typical weathering pattern caused by rain and prevailing wind is illustrated in **Fig. 3**. Parts of the building façade are clean in areas where it is washed by rain, even though the remainder of the building has become soiled.

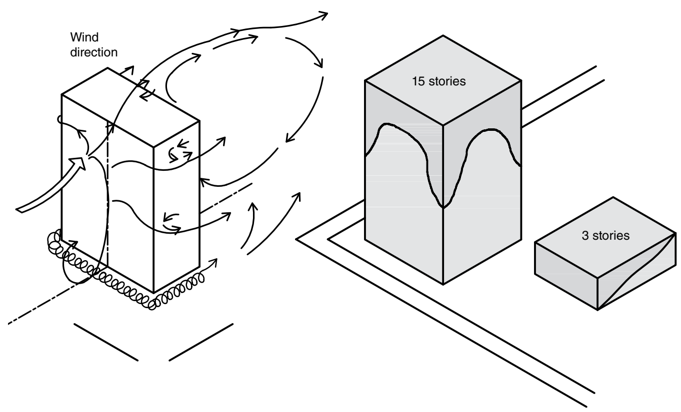

Figure 2 Wind movement around building and rain wetting of façades.

Figure 3 Water washing and dirt deposits.

Rounded or splayed corners reduce wind speed at the edges of buildings and may be useful to avoid the heavy concentrations of driving rain that are typical of these locations. Also, continuity of water flow between surfaces is improved when corners between them have rounded instead of sharp edges. A joint, groove, or projection near a corner with a long return should be used to catch the rainwater and prevent partial dirt washing from water blown around the corner.

The raindrops that reach a wall surface are absorbed to different extents depending on absorption and moisture content of the wall material. Precast concrete normally has a medium to low water absorbency of 5 to 6% by weight or 12 to 14% by volume. Water run-off on concrete surfaces consists of a very thin layer, 0.01 in. (0.25 mm) thick, and only occurs if the absorption of the concrete is lower than a certain value. The run-off flows slowly (up to 3 ft./min. [0.9 m/min.]) and vertically down the wall with lateral winds having an insignificant influence. When the water reaches lower sections, which have been struck by less driving rain and are drier, it is absorbed. The dirt accompanying the water is deposited in new places, unevenly soiling the surface. Also, a façade with high absorption normally becomes wet rapidly and remains damp for a longer period than a façade with low absorption. Airborne dirt (soiling particles) adheres easily to high absorption concrete. It is desirable to break up large areas of concrete, extending over several stories, with horizontal features that either collect or throw off the water at intermediate positions. These features will reduce the amount of water on the surface, reduce the differences between panels at different levels on the façade, make the change from washed to unwashed

Figure 4 (a) Water flow over glass depositing dirt.

Figure 4 (b) Water flow over glass depositing dirt soiling pattern.

into a gradation instead of a clearly visible line and by producing interest and shadows will make any changes less noticeable.

Surface tension causes droplets of water to converge on non-porous surfaces such as glass and metal and to drain in irregular streams. Glass areas cause build-up of water flow. Because glass is a non-absorbent material, the flow rate of water down its surface is fast and in discrete streams rather than as a continuous film with little time lag in its throw-off. By contrast, rainwater flowing down an adjacent concrete wall surface will be slower (depending on the surface texture) and its throw-off will be less complete. As a result, there is a concentration of water at the base of a window or glass curtain wall—the very thing the designer must guard against if differential patterning is to be avoided. This flow must be dissipated, breaking up its concentration. Furthermore, there is always a tendency for water flow to be in greater volume at the edges of the glass or at the mullions than in its center, (the smallest amount of wind tends to drive rain toward the edges of the glass). **Fig. 4(a) and (b)** show a soiling pattern caused by water run-off carrying particulate matter down the mullion and over the horizontal precast concrete. In Figure 4(a), an attempt to minimize staining resulted in rustications being cut under the mullions after the panels were in place. Shadows on rustications usually help mask streaks particularly when the recessed depth is equal to or greater than the recess width.

The water run-off on concrete surfaces has a tendency to divide into separate streams determined by microscopic irregularities or differences in absorption of the surface when the water layer thickness decreases below a critical value. This breakdown into irregular, separate streams takes place mainly on smooth or lightly textured surfaces but can also occur on surfaces with exposed aggregates. However, a uniformly distributed, broken flow, which results in slow water run-off, is more likely to occur over heavily textured materials, (**Fig. 5**). These streams recur at the same locations on walls or windows during most rainfalls and are reflected in the soiling pattern. The streams of water broaden out laterally when they meet horizontal or moderately sloping obstacles. They also follow surfaces facing downward (horizontal surfaces) in a similar manner. Consequently, the design of drips is extremely important. Surface tension allows water flow to take place along the underside of horizontal surfaces. Therefore, outward-sloping ledges, soffits, and bullnoses should have a drip groove in the underside to prevent particulate laden water running back onto the façade below and causing dirt streaking.

When a small volume of water maintains contact with a relatively large area of glass, conditions may be conducive to leaching of the alkaline materials in the glass. The interaction of glass and water results in the replacement of the sodium ions in the glass with hydrogen ions from the water. As sodium ions accumulate and hydrogen ions decrease in a thin film of water, the liquid will increase in alkalinity at a much greater rate than if it were absorbed into a large volume of water. Also, this reaction and, the solution pH increases much more rapidly at elevated temperature (140°F vs. 73°F [60°C vs. 23°C]). As long as the alkaline concentrations of the resulting solution remain below pH level of 8.5 (the threshold of permanent surface damage), glass etching does not occur. However, if the evaporation rate is very slow, and the pH level increases to 9.0 or above, glass network dissolution (glass etching) displaces ion exchange as the predominant reaction mechanism. Any factor that increases the length of time moisture is in contact with glass during wet-dry cycles is likely to speed tenacious staining and possibly contribute to glass etching. One of the most common contributors of differential wetting is dirt or dust. Dirt accumulation on glass holds the water on the glass longer causing moisture to attack the surface. The finely divided damp materials in contact with glass cause the glass constituents to dissolve slightly and be redeposited at the evaporating edge of the material, resulting in tenacious deposits. Frequent washing of the windows tends to remove the gel before it becomes hard, minimizing staining and etching of the glass.

Figure 5 Water flow over smooth versus rough texture.

A common response to the etching of glass in concrete structures is that concrete contributes alkaline materials to the run-off water. Hydration of cement results in the formation of hydrated calcium silicates (CSH), Ca $(OH)_2$, and aluminates, and the remaining water in the concrete becoming highly alkaline. Atmospheric acids (NO_x, SO_x, and $C0_2$) neutralize low concentrations of these alkalies from concrete to produce less alkaline salts of calcium, sodium, or potassium. Of these reaction products, only the carbonates of sodium and potassium provide the most soluble alkaline salts. However, even these salts are quickly converted to the bicarbonates that are only very weakly alkaline. Because the atmosphere is usually very acid in the larger cities (refer to Fig. 1), low concentrations of leached alkali (high pH) will be neutralized.

Although laboratory studies have demonstrated that glass can be susceptible to alkaline-induced surface damage, it does so under conditions that do not prevail in the environments typically encountered by glazing systems. A solution of calcium hydroxide (pH 11.5) placed on glass at 140°F (60°C) in a controlled environment to retard evaporation does not cause chemical erosion or etching after 20 hours. In the field, it is only the last water droplets after a rain, adhering to glass, that could present a threat to surface quality via alkaline etching, if indeed the solution pH is 9.0 or greater and the residence time is well beyond 24 hours. It is doubtful that these droplets could exist intact for the periods required for severe alkaline etching to develop. Repeated deposition and evaporation can eventually lead to tenacious deposits and subsequent chemical etching.

Concrete frames at window heads should be designed so they don't splay down and back toward the glass, unless drip details are incorporated into the frame. The drip section should be designed in relation to the slope of the concrete surface (**Fig. 6**) to prevent water from bridging the drip. To avoid chipping, the drip should not be located closer than 1½ in. (38 mm) to the edge of the precast concrete unit. Where the window is not 2 in. (50mm) or more back from the face of the panel, it is difficult to get a drip groove in the panel.

Drips also prevent water (after a storm) from slowly running over the window glass, a primary cause of glass streaking. Without drips to prevent slow run-off and differential wetting of the windows, dirt or dust accumulation on windows will increase the length of time the last water droplets are in contact with the glass during wet-dry cycles. Contact of the finely divided damp dirt or dust with the glass may cause glass constituents to dissolve slightly and be redeposited possibly resulting in glass staining or etching. The time period

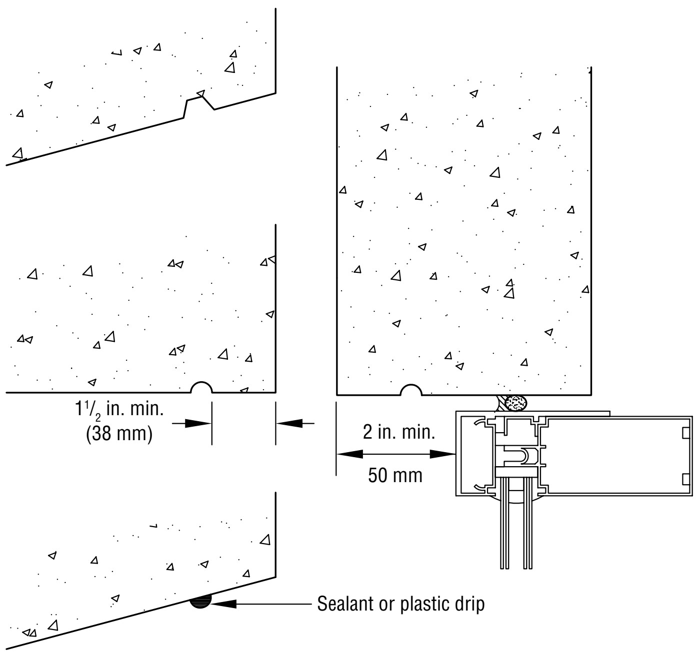

Figure 6 Design of water drip in relation to slope.

for a stain to result depends to some degree on ambient temperatures with warmer temperatures causing the stain to occur sooner. Periodic window washing (every 90 to 180 days depending on dirt accumulation) is important in minimizing stains from occurring on the glass. By doing this cleaning, deposits will not have time to accumulate.

Water will leave a drip at its lowest point and it is important to follow its course thereafter. Small chips and cracks in the building surface may concentrate the flow, so that water will bridge drip details and allow wetting of the surface below. If particulate laden water falls onto other surfaces, the problem may be merely relocated. However, if the wind tends to spread the water out on the surface below, uniformity of weathering may be obtained. To avoid streaks on the sides of window panels, the drip may be stopped about 2 in. (50 mm) short of the window sides.

A clear sealant bead applied to precast concrete units after erection, or plastic drips glued to the concrete, are remedial drip solutions used with varying success depending on their care in application. A drip incorporated initially into the precast concrete or window frame is the least-costly and best solution. **Figs. 7 (a) and (b)** show the use of an extrusion (either aluminum or neoprene) across the head of a window which have either an integral gutter or extended drip lip of at least 1 in. (25 mm) as remedial drip details.

Although sealers are not a substitute for proper design for water run-off they do improve concrete's weathering characteristics in urban or industrial areas by reducing the absorption of moisture and increasing rainwater run-off. A combination of a base coat application of a penetrating silane sealer with a topcoat application of methyl methacrylate resin sealer may be the most effective. Sealers should be guaranteed by the supplier or applicator not to stain, soil, darken, or discolor the precast concrete finish. The use of sealers on precast concrete in locations having little or no air pollution or in dry climates is not recommended due to the additional cost, recurring periodic maintenance applications, and uncertain results of the sealer application.

The vertical angle of a surface has a major influence on the quantity of pollutants it collects and how they are discharged during rain. **Fig. 8** shows the volume of rain assumed to hit a building surface depending on the orientation of the surface. For diagrammatic purposes, the angle of rainfall direction is assumed to be 10 deg. from the vertical. However, the variability of rain under actual conditions makes all but a general prediction difficult. Vertical or near-vertical surfaces receive insufficient rainwater to be self-cleansing. Steep forward-sloping surfaces usually weather cleaner. Large areas may begin to collect dirt at the lower end unless the angle is steep. With heavy rain, the dirt on horizontal surfaces and surfaces that have little slope may be partially washed off, streaking the surfaces below. In the case of light rain or drizzle, the dirt may collect and slowly flow down other surfaces in the general direction of the water flow, resulting in pronounced, random streaking. Backward-sloping surfaces collect little or no rain but are likely to be subject to a partial, nonuniform water flow from above, which may carry dirt and cause serious streaking. Backward-sloping surfaces are often seen in shadow. In this case, the accumulation of dirt is not particularly noticeable if the dirt is acquired evenly without disfiguring streaks. The following guidelines are derived from the weathering of exposed surfaces:

- Avoid horizontal planes—they collect the most dirt and are the most exposed to rain.
- Use steeply sloping rather than flat upper surfaces—the advantage of a sloping upper surface is that the dirty water is immediately drained away. For example, sills should have a minimum slope of 2 % to ensure water flow away from windows and minimize dirt accumulation. Adopting a steep slope and a limited height encourages run-off of rain and complete washing. If there is a risk of an uneven staining pattern, then opt for a darker color and/or a complex surface texture, for example, deep grooves.

Parapets should be designed to avoid run-off from flat roofs onto the façade. A parapet of sufficient height (8 to 12 in. [200 to 300 mm]) will normally prevent water on the roof from blowing over the parapet onto the face of the building. The top of the parapet should slope backward (with a 1:4 slope) toward the roof for its full width and be narrow so that dirt accumulating on them does not cause streaking on the building face when washed off.

(a)

(b)

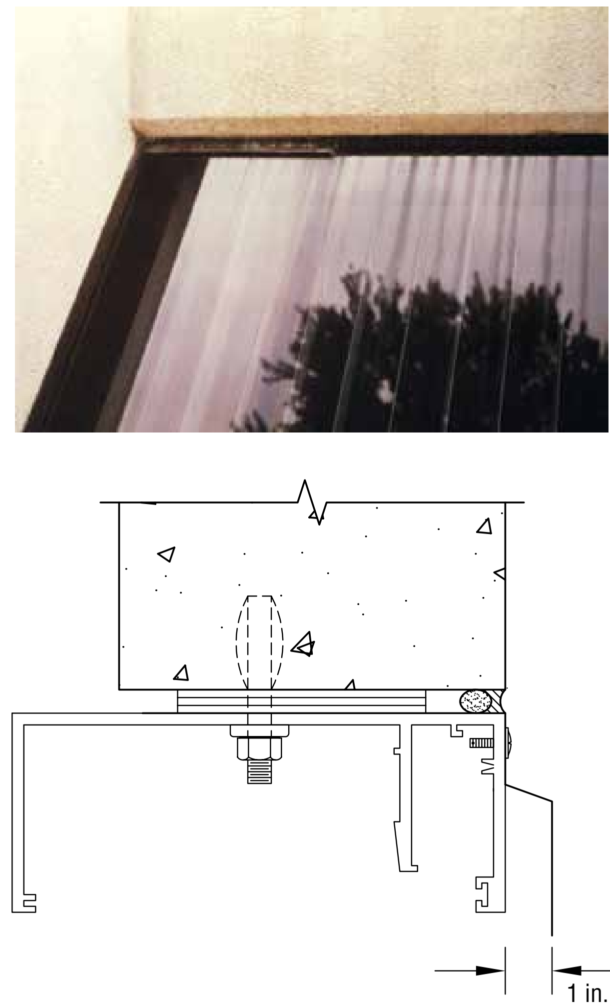

Figure 7 Gutter or drip incorporated as drip detail.

- Avoid run-off into areas in the rain shadow (where little rain will fall and dirt streaking is likely).
- For vertical surfaces, detail surface finishes that disperse rainwater flow over the surface or provide vertical striations that direct the flow more evenly.
- Avoid run-off from horizontal or gently sloping upper surfaces on vertical sections of walls. Investigate whether the combination of the two surfaces cannot be replaced by a slope. The pattern of the spandrel under the windows is influenced by this.

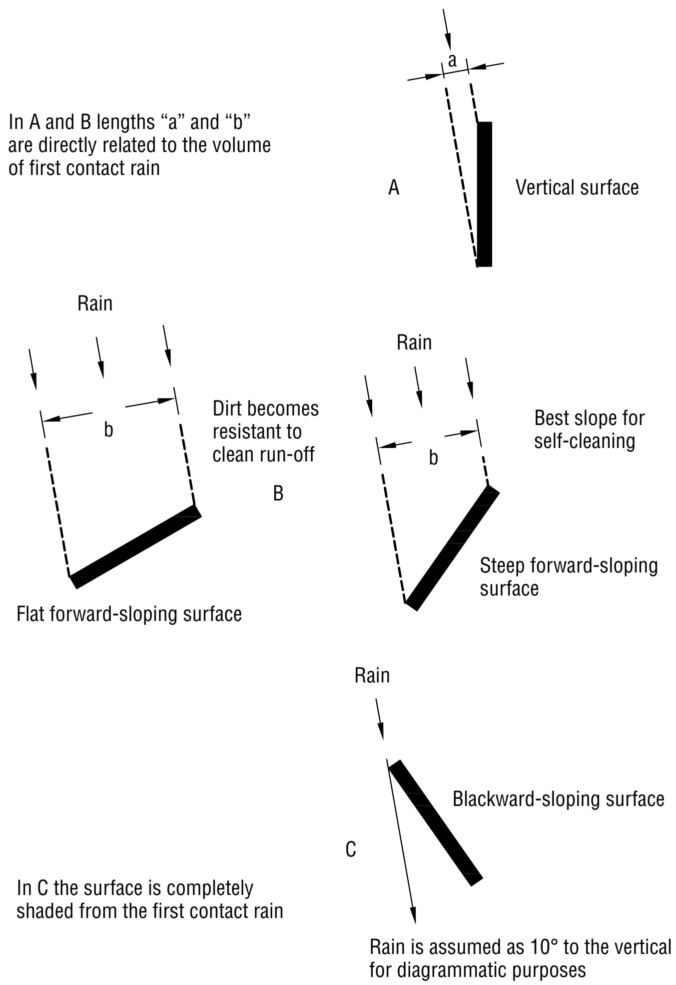

Figure 8 Volume of rain likely to hit wall surfaces.

- Every inclined or vertical surface with large projections must be provided with a well-profiled drip in order to prevent the rain running off into the rain-shadow area.

The façade geometry of buildings is usually responsible for local concentrations of run-off which should be avoided. Such concentrations lead to the characteristic marking patterns frequently observed on building surfaces: dirt accumulation, dirt washing, and white washing.

New buildings may show dirt washing at locations of concentrated run-off while their over-all surfaces are still quite clean. Later, the same areas may exhibit white washing (lighter, cleaner streaks) after adjacent surfaces have been darkened by dirt accumulation.

Adjacent precast concrete units should have faces aligned within accepted industry tolerances. Any discrepancy may pass undetected on a new building, but weathering will eventually emphasize the offset with uneven staining of adjacent units.

The intersection of horizontal and vertical projecting elements almost always creates dirt streaks. Such streaks run back from the edge of exposed columns and below the ends of horizontal elements even when they are steeply sloped at the top surface. To avoid such streaks, the horizontal element should be stopped short of the column. This confines rain run-off to the horizontal element and permits unimpeded washing of the column. Channeling of the column faces also will help prevent water from running back along the edges.

Water flowing laterally or diagonally downward on a surface will concentrate where it encounters vertical projections or recesses. The secondary airflow due to wind is also important. It concentrates run-off at the outside corners of the building, at columns, and at inside corners of vertical projections. Surface tension contributes to this effect by preventing flow back from vertical edges of small elements such as window mullions, often concentrating the flow at the corners.

In areas where nearby buildings show the undesirable effects of weathering and the local atmosphere is laden with pollutants, it is recommended that consideration be given to the use of sealers to increase rain run-off, reduce surface absorption of the concrete, and facilitate cleaning of the surface.

Surface Finish

Concrete surface finishes vary considerably in their ability to take up and release dirt under weathering conditions. They should therefore be chosen for their so-called "self-cleansing" properties. But the selection of color and texture may have an aesthetic significance greater than the effects of weathering. The economics of varying the surface finish from one part of the building to another should be investigated as the weathering characteristics will be different.

The surface of smooth precast concrete is hard and impervious and easily streaked by rain, unless there is enough water to form a complete film on the surface. Weathering patterns are determined by the shape and smoothness of the units and joints, which are particularly vulnerable. Any irregularity in a smooth surface will be exaggerated by weathering patterns. Non-repeating, irregular, and concentrated streams tend to form on smooth or lightly textured materials. Light-toned and smooth surfaces accentuate the contrast between washed and unwashed areas.

Textured finishes accumulate more dirt, but they can maintain a satisfactory appearance. The aggregate tends to break up and distribute water run-off more evenly, reducing the streaking that appears on smooth surfaces. Textured finishes also have a slower drain-off because each stream is small. The irregularities and shadows on the surface also tend to mask discoloration. It is not reasonable, however, to expect an exposed-aggregate finish to deal with all problems of weathering. The way water moves on such a surface is different, but concentrated flows or their effects will still be visible and must be controlled.

Rounded aggregates are preferred because they tend to collect less dirt than angular aggregates with rough texture. However, dirt pickup is generally confined to the matrix. For this reason, as well as for architectural appearance, the area of exposed matrix between aggregate particles should be minimized. The smooth, nonporous surfaces of the aggregates allow less dirt to deposit and promote more run-off to increase washing of the surface. At the same time, a slightly recessed or a darker matrix helps to absorb and mask pollution deposition.

Extreme color differences between aggregates and matrix will create uniformity problems. For example, large exposed aggregates of light color provide heavily textured surfaces that may seem to be very dirty with time because the matrix becomes very dark and the high spots of the aggregates are washed clean. In some cases, uniformly colored light surfaces contrasted with uniformly dark-colored surfaces may be used to accentuate the depth of relief on a building face. Smooth units made with dark-colored sands will slowly become darker with age when subject to weathering because the surface film of cement paste erodes away, exposing the sand. Therefore, wide differences between the color of the matrix and the sand should be avoided.

The use of appropriate colors and textured surfaces can help to mask the effect of dirt deposits. The overall darkening in tone that takes place is unlikely to be objectionable unless streaking occurs. Medium textured finishes may still allow water to run or be wind-driven into streams, causing irregular streaks. Vertical ribs or flutes that help the designer give expression to a façade will also help to control the run-off and prevent it from spreading horizontally. As dirt collects in the hollows, it emphasizes the shadow and, therefore, the texture itself. The rib must not be too wide otherwise a soiled pattern may develop in the middle area of the rib's upper surface. If the ribs are terminated above the lower edges of the walls, streaking below the ribs may occur depending on the depth of projection and the wind force and direction. As water reaches the bottom edge of a vertical or inclined panel, surface-tension effects cause it to slow down before dripping clear and it tends to deposit any dirt it has been carrying. Horizontal ribs or flutes spread stains rather than prevent them and can be used to protect the underlying surface by deflecting the flow of water. Water flows on diagonal ribs create a weathering pattern difficult to predict.

Figure 9 (a) Self-cleaning concrete on Jubilee Church, Rome, Italy.

Figure 9 (b) North-facing cladding was a constant mildew-problem—self-cleaning concrete was the solution.

Self-Cleaning Concrete

White or gray cement manufactured with nanoparticles of titanium dioxide becomes a photocatalyst. The architectural precast concrete face mix containing the photocatalyst uses the sun's rays (ultraviolet light) to accelerate the formation of strong oxidizing reagents which results in decomposition of organic and inorganic pollutants which are washed-off by rain. This revents pollutants from a cumulating. The catalyst is not consumed in the reaction. The concrete surface thereby becomes self-cleaning over time while ensuring the same physical and mechanical properties of conventional concrete. In addition, synthetic iron-oxide pigments can be used to color the concrete.

The first use of this cement for production of precast panels was for the graceful "sails" in the landmark Jubilee Church (Dives in Misericordia), (**Fig. 9a**) completed in 2003 in Rome, Italy (designed by Richard Meier & Partners).

With local high humidity and rainfall levels paired with a warm climate, the white precast concrete addition to the LSU Basketball Practice Facility in Baton Rouge, La., needed to resist the inevitable mildew problems, (**Fig. 9b**). The use of a self-cleaning photocatalytic cement was the answer.

Ascent 2013 – Weathering

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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 Learning Unit associated with this educational program.

Learning Objectives:

1. Define what weathering is.
2. Explain how the effects of weathering on a building can be predicted.
3. Describe how different finishes and colors affect weathering.
4. Explain how concrete can be made to be self-cleaning.

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

PCI-Certified Plants

(as of July, 2013)

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.

Visit www.pci.org for the most up-to-date listing of PCI-Certified plants.

ALABAMA
Gate Precast Company, Monroeville (251) 575-2803 .... **A1, C4A**
Hanson Pipe and Precast Southeast, Pelham (205) 663-4681 .... **B4, C4**
Standard Concrete Products, Theodore (251) 443-1113 .... **B4, C2**

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

ARIZONA
Coreslab Structures (ARIZ) Inc., Phoenix (602) 237-3875 .... **A1, B4, C4A**
CXT Concrete Ties, Tucson (520) 644-5703 .... **C2**
Royden Construction Company, Phoenix (602) 484-0028 .... **B4**
TPAC, Phoenix (602) 262-1360 .... **A1, B4, C4A**

CALIFORNIAA
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 .... **B3, C3**
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., Stockton (209) 466-4212 .... **C2,**
Oldcastle Precast, Inc., Perris (951) 657-6093 .... **B4, C2A**
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, Denver (303) 480-1111 .... **A1, C3A**
Rocky Mountain Prestress LLC, 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**
Florida Precast Industries, Inc., Sebring (863) 655-1515 .... **C2**
Gate Precast Company, Jacksonville (904) 757-0860 .... **A1, B4, C3A**
Gate Precast Company, Kissimmee (407) 847-5285 .... **A1, C2**
Metromont Corporation, Bartow (863) 440-5400 .... **A1, C3A**
Pre-Cast Specialties Inc. (*), Pompano Beach (800) 749-4041 .... **C4**
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**
Colonial Construction, Concrete, Precast, LLC, Elberton (941) 698-4180 .. **C2**
ConArt Precast, LLC, Cobb (229) 853-5000 .... **A1, AT, C3**
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, Conley (800) 849-6383 .... **C4A**
Tindall Corporation, Conley (800) 849-6383 .... **C2A**

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, C3**
Illini Concrete Company of Illinois, LLC, Tremont (309) 925-5290 .. **B3, B3-IL**
Illini Precast, LLC, Marseilles (708) 562-7700 .... **B4, B4-IL, C3**
Lombard Architectural Precast Products Co., Alsip (708) 389-1060 .... **A1**
Mid-States Concrete Industries, South Beloit (608) 364-1072 .... **A1, B3, B3-IL, C3A**
Prestress Engineering Corporation, Blackstone (815) 586-4239 **B4, B4-IL, C4**
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**
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 .... **B3, C4**

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, Lexington (260) 724-7117 **B4, B4-IL, 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 Products,
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**

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

MAINE
Oldcastle Precast, Auburn (207) 784-9144 .... **B2, C1**

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

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MICHIGAN

International Precast Solution, 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 **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**
Hanson Structural Precast Midwest, Inc., Maple Grove (763) 425-5555 **A1, C4A**
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**

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

Missoula Concrete Construction, Missoula (406) 549-9682 **A1, B3, C3A**
Montana Prestressed Concrete, Billings (605) 718-4111 **B4, C3**
Montana Prestressed Concrete - MT City Plant, Montana City (406) 442-6503 **B4**

NEBRASKA

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 Township (609) 689-3700 **B4, C4**
Northeast Precast*, Millville (856) 765-9088 **A1, B2, 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 **B3, C1**
The L.C. Whitford Materials Co., Inc., Wellsville (585) 593-2741 **B4, C3**

NORTH CAROLINA

Gate Precast Company, Oxford (919) 603-1633 **A1, C2**
International Precast Inc., Siler City (919) 742-3132 **A1, C3A**
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 **C3**
Prestress Services Industries of Ohio, LLC, Mt. Vernon (740) 393-1121 **B3, C1**
Prestress Services Industries of Ohio, LLC, Mt. Vernon (800) 366-8740 **B4, C3**
Sidley Precast, Thompson (440) 298-3232 **A1, C4A**

OKLAHOMA

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 **C1**
Concrete Safety Systems, LLC, Bethel (717) 933-4107 **B1A, C1A**
Conewago Precast Building Systems, Hanover (717) 632-7722 **A1, C2A**
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**
Newcrete Products, Roaring Spring (814) 224-2121 **B4, C4**
Nitterhouse Concrete Products, Inc., Chambersburg (717) 267-4505 **A1, C4A**
Northeast Prestressed Products, LLC, Cressona (570) 385-2352 **B4, C3**
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**

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, C2**
Tindall Corporation, Fairforest (864) 576-3230 **A1, C4A**

SOUTH DAKOTA

Gage Brothers Concrete Products Inc., 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, C4**
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 **B1, C1A**
Eagle Precast Corporation, Decatur (940) 626-8020 **A1, C3**
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**
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, C3A**
Rocla Concrete Tie, Inc., Amarillo (806) 383-7071 **C2**
Tindall Corporation, San Antonio (210) 248-2345 **A1, C3A**

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UTAH

Hanson Structural Precast Eagle, Salt Lake City (801) 966-1060 **A1, B4, C4AG**
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**

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**
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**
Central Pre-Mix Prestress Co., Spokane (509) 533-0267 .... **A1, B4, C4**
Concrete Technology Corporation, Tacoma (253) 383-3545 .... **B4, C4**
CXT, Inc., Spokane (509) 921-7878 .... **C2**
CXT, Inc., Spokane (509) 921-8716 .... **B1**
EnCon Northwest, LLC, Camas (360) 834-3459 .... **B1**
EnCon Washington, LLC, Puyallup (253) 846-2774 .... **B1, C2**
Wilbert Precast, Inc., Yakima (509) 248-1984 .... **B3, C3**

WEST VIRGINIA

Carr Concrete Corporation, Waverly (304) 464-4441 .... **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**
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, C3**
MidCon Products, Inc., Hortonville (920) 779-4032 .... **A1, C1**
Spancrete, Inc., Valders (920) 775-4121 .... **B4, C3**
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 52-555-0770071 .... **A1, G**
Willis De Mexico S.A. de C.V., Tecate 52-665-6552222 .... **A1, C1, G**

CANADA

ALBERTA

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, C4**

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., Alma (418) 668-6161 .... **A1, C3A, G**
Betons Prefabriques du Lac, Inc., Alma (418) 668-6161 .... **A1, C2**
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 July, 2013)

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 in blue.

ARKANSAS

Coreslab Structures (ARK) Inc., Conway (501) 329-3763 .... S2

ARIZONA

Coreslab Structures (ARIZ), Inc., Phoenix (602) 237-3875 .... S2, A
TPAC, Phoenix (602) 262-1360 .... S2, A

CALIFORNIA

Coreslab Structures (L.A.), Inc., Perris (951) 943-9119 .... S2, A
Walters & Wolf Precast, Fremont (510) 226-9800 .... A

COLORADO

Encon Field Services, LLC, Denver (303) 287-4312 .... S2, A
Gibbons Erectors, Inc., Englewood (303) 841-0457 .... S2, A
Rocky Mountain Prestress, Denver (303) 480-1111 .... S2, A

CONNECTICUT

Blakeslee Prestress, Inc., Branford (203) 481-5306 .... S2
The Middlesex Corporation, West Hartford (860) 206-4404 .... S2
The Smedley Company, Branford (203) 315-6066 .... A

FLORIDA

All Florida Erectors and Welding, Inc., Apopka (407) 466-8556 .... S2
Concrete Erectors, Inc., Altamonte Springs (407) 862-7100 .... S2, A
Finfrock Industries, Inc., Orlando (407) 293-4000 .... S2, A
Florida Builders Group, Inc., Miami (305) 278-0098 .... S2
Gate Precast Erection Co., Kissimmee (407) 847-5285 .... A
James Toffoli Construction Company, Inc., Fort Myers (239) 479-5100 .... S2, A
Pre-Con Construction of Tampa Inc., Tampa (813) 626-2545 .... S2, A
Prestressed Contractors Inc., Palm Beach Gardens (561) 741-4369 .... S1
Solar Erectors U. S. Inc., Medley (305) 825-2514 .... S2, A
Specialty Concrete Services, Inc., Altoona (352) 669-8888 .... S2, A
Structural Prestressed Industries, Inc., Medley (305) 556-6699 .... S2
Summit Erectors, Inc., Jacksonville (904) 783-6002 .... S2, A

GEORGIA

Big Red Erectors Inc., Covington (770) 385-2928 .... S2, A
Precision Stone Setting Co., Inc., Hiram (770) 439-1068 .... S2, A
Rutledge & Son's, Woodstock (770) 592-0380 .... S2

IOWA

Cedar Valley Steel, Inc., Cedar Rapids (319) 373-0291 .... S2, A
Topping Out Inc. / dba Northwest Steel Erection, Des Moines (800) 247-5409 .... S2

IDAHO

Precision Precast Erectors, LLC, Worley (208) 660-5223 .... S2, A

ILLINOIS

Area Erectors, Inc., Rockford (815) 562-4000 .... S2, A
Creative Erectors, LLC, Rockford (815) 229-8303 .... S2, A
Mid-States Concrete Industries, South Beloit (800) 236-1072 .... S2
Trinity Roofing Service Inc., Blue Island (708) 385-7830 .... S1

INDIANA

Stres Core Inc., South Bend (574) 233-1117 .... S1

KANSAS

Carl Harris Co., Inc., Wichita (316) 267-8700 .... S2, A
Crossland Construction Company, Inc., Columbus (620) 429-1414 .... S2, A
Ferco, Inc., Salina (785) 825-6380 .... S2
Topping Out Inc. / dba Davis Erection Kansas City, Kansas City (800) 613-9547 .... S2

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MASSACHUSETTS

Prime Steel Erecting, Inc., North Billerica (978) 671-0111 ..... **S2, A**

MARYLAND

DLM Contractors, LLC, Upper Marlboro (301) 877-0000 ..... **S2, A**
E & B Erectors, Inc., Pasadena (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**
Mid Atlantic Precast Erectors, Inc., Baltimore (410) 837-1641 ..... **A**
Oldcastle Building Systems Div. / Project Services, Baltimore (518) 767-2116 ..... **S2, A**

MAINE

American Aerial Services, Inc., Falmouth (207) 797-8987 ..... **S1**
Cianbro Corporation, Pittsfield (207) 679-2435 ..... **S2**
Reed & Reed, Inc., Woolwich (207) 443-9747 ..... **S2, A**

MICHIGAN

Assemblers Precast & Steel Services, Inc., Saline (734) 429-1358 ..... **S2, A**
Devon Contracting, Inc., Detroit (313) 221-1550 ..... **S2, A**
G2 Inc., Cedar Springs (616) 696-9581 ..... **S2, A**
Pioneer Construction Inc., Grand Rapids (616) 247-6966 ..... **S2, A**

MINNESOTA

Amerect, Inc., Newport (651) 459-9909 ..... **A**
Fabcon Precast, LLC, Savage (952) 890-4444 ..... **S2**
Hanson Structural Precast Midwest, Inc., Maple Grove (763) 425-5555 ..... **S2, A**
Landwehr Construction Inc., St. Cloud (320) 252-1494 ..... **S2**
Molin Concrete Products Company, Lino Lakes (651) 786-7722 ..... **S2, A**
Wells Concrete, Wells (507) 553-3138 ..... **S2, A**

MISSOURI

Acme Erectors, Inc., St. Louis (314) 647-1923 ..... **S2, A**
JE Dunn Construction Company, Kansas City (816) 474-8600 ..... **S2, A**
Prestressed Casting Co., Springfield (417) 869-7350 ..... **S2, A**

MISSISSIPPI

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

NORTH CAROLINNA

Buckner Steel Erection Inc., Graham (336) 376-8888 ..... **S2**
Carolina Precast Erectors, Inc., Taylorsville (828) 635-1721 ..... **S2, A**

NORTH DAKOTA

Comstock Construction, Wahpeton (701) 642-3207 ..... **S2**
PKG Contracting, Inc., Fargo (701) 232-3878 ..... **S2**
Wells Concrete, Grand Forks (701) 772-6687 ..... **S2**

NEBRASKA

Moen Steel Erection, Inc., Omaha (402) 884-0925 ..... **S2**
Structural Enterprises Incorporated, Lincoln (402) 423-3469 ..... **S2**
Topping Out Inc. / dba Davis Erection Lincoln, Lincoln (800) 881-2931 ..... **S2**
Topping Out Inc. / dba Davis Erection Omaha, Omaha (800) 279-1201 ..... **S2, A**

NEW HAMPSHIRE

American Steel & Precast Erectors, Inc., Greenfield (603) 547-6311 ..... **S2, A**

NEW JERSEY

CRV Precast Construction LLC, Eastampton (800) 352-1523 ..... **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

Ferreri Concrete Structures, Inc., Albuquerque (505) 344-8823 ..... **S2**
Structural Services, Inc., Albuquerque (505) 345-0838 ..... **S2, A**

NEW YORK

J.C. Steel Corp., Bohemia (631) 563-3545 ..... **A**
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**
Yonkers Contracting Company, Inc., Yonkers (914) 636-2301 ..... **S1**

OHIO

Precast Services, Inc., Twinsburg (330) 425-2880 ..... **S2, A**
Sidley Precast Group, Thompson (440) 298-3232 ..... **S2**
Sofco Erectors, Inc., Cincinnati (513) 771-1600 ..... **S2, A**

OKLAHOMA

Allied Steel Construction Co., LLC, Oklahoma City (405) 232-7531 ..... **S2, A**
Bennett Steel, Inc., Sapulpa (918) 260-0773 ..... **S1**
Coreslab Structures (OKLA), Inc., Oklahoma City (405) 632-4944 ..... **S2, A**

PENNSYLVANIA

Century Steel Erectors, Kittanning (724) 545-3444 ..... **S2, A**
Conewago Enterprises, Inc., Hanover (717) 632-7722 ..... **S2**
High Concrete Group, Denver (717) 336-9300 ..... **S2, A**
Kinsley Construction Inc., 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**
Patterson Construction Company, Inc., Monongahela (724) 258-4450 ..... **S1**

SOUTH CAROLINA

Davis Erecting & Finishing, Inc., Greenville (864) 220-0490 ..... **S2, A**
Florence Concrete Products Inc., Florence (843) 662-2549 ..... **S2**
Tindall Corporation, Fairforest (864) 576-3230 ..... **S2**

SOUTH DAKOTA

Fiegen Construction Co., Sioux Falls (605) 335-6000 ..... **S2, A**

TENNESSEE

Mid South Prestress, LLC, Pleasant View (615) 746-6606 ..... **S2**
River City Erectors, LLC, Rossville (901) 861-6174 ..... **A**

TEXAS

Derr and Isbell Construction, LLC, Euless (817) 571-4044 ..... **S2, A**
Empire Steel Erectors LP, Humble (281) 548-7377 ..... **A**
Gate Precast Company, Pearland (281) 485-3273 ..... **S1**
Gulf Coast Precast Erectors, LLC, Hempstead (832) 451-4395 ..... **S2**
Precast Erectors, Inc., Hurst (817) 684-9080 ..... **S2, A**

UTAH

Hanson Structural Precast Eagle, Salt Lake City (801) 966-1060 ..... **S2, A**
IMS Masonry, Lindon (801) 796-8420 ..... **A**
OutWest C & E Inc., Bluffdale (801) 446-5673 ..... **S2, A**

VIRGINIA

Sprinkle Masonry Inc., Chesapeake (757) 545-8435 ..... **A**
The Shockey Precast Group, Winchester (540) 665-3253 ..... **S2, A**

VERMONT

CCS Constructors Inc., Morrisville (802) 888-7701 ..... **S2**

WASHINGTON

Central Pre-Mix Prestress Co., Spokane Valley (509) 536-3334 ..... **S2, A**

WISCONSIN

Miron Construction Co. Inc., Neenah (920) 969-7000 ..... **S2, A**
Spancrete, Valders (920) 775-4121 ..... **S2, A**
The Boldt Company, Appleton (920) 225-6127 ..... **S2, A**

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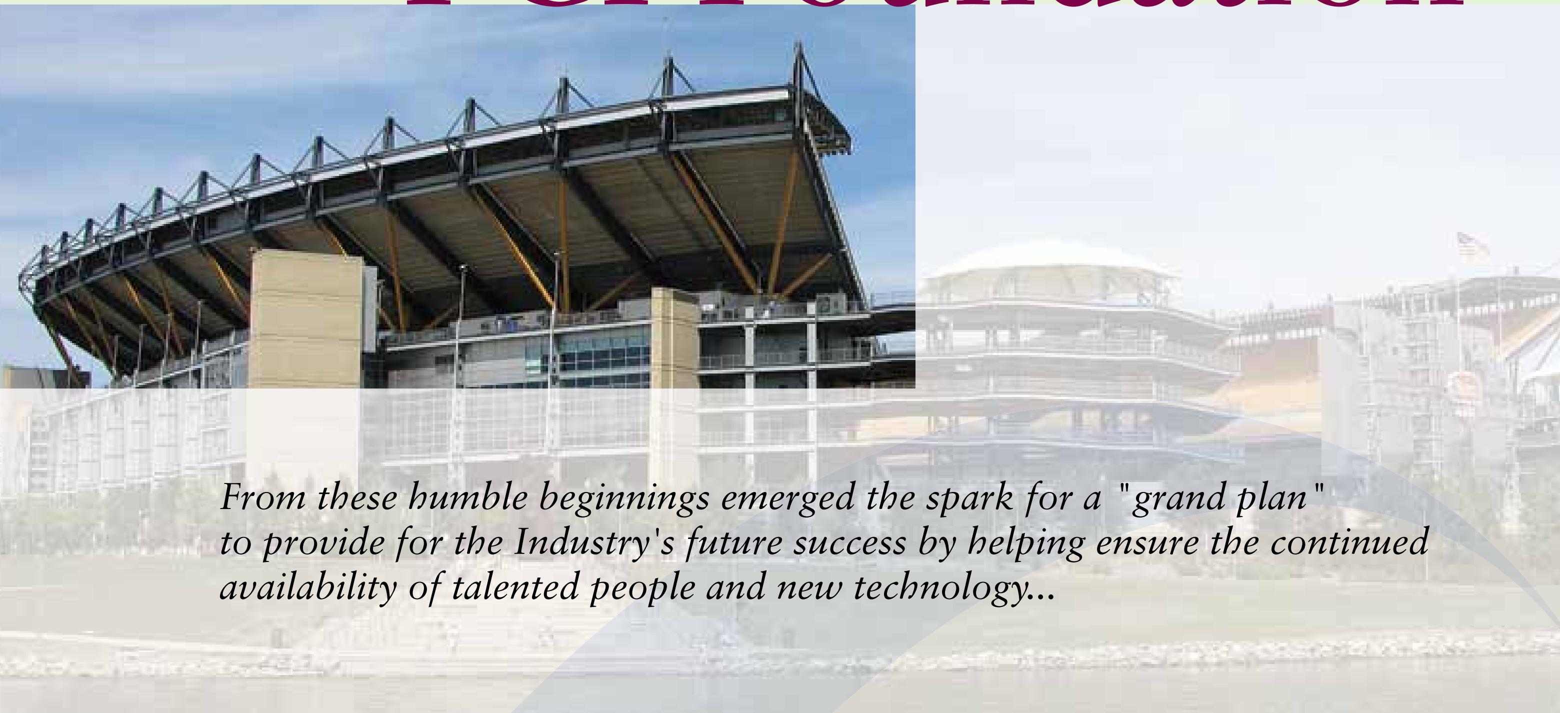

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