HIGHER EDUCATION ISSUE

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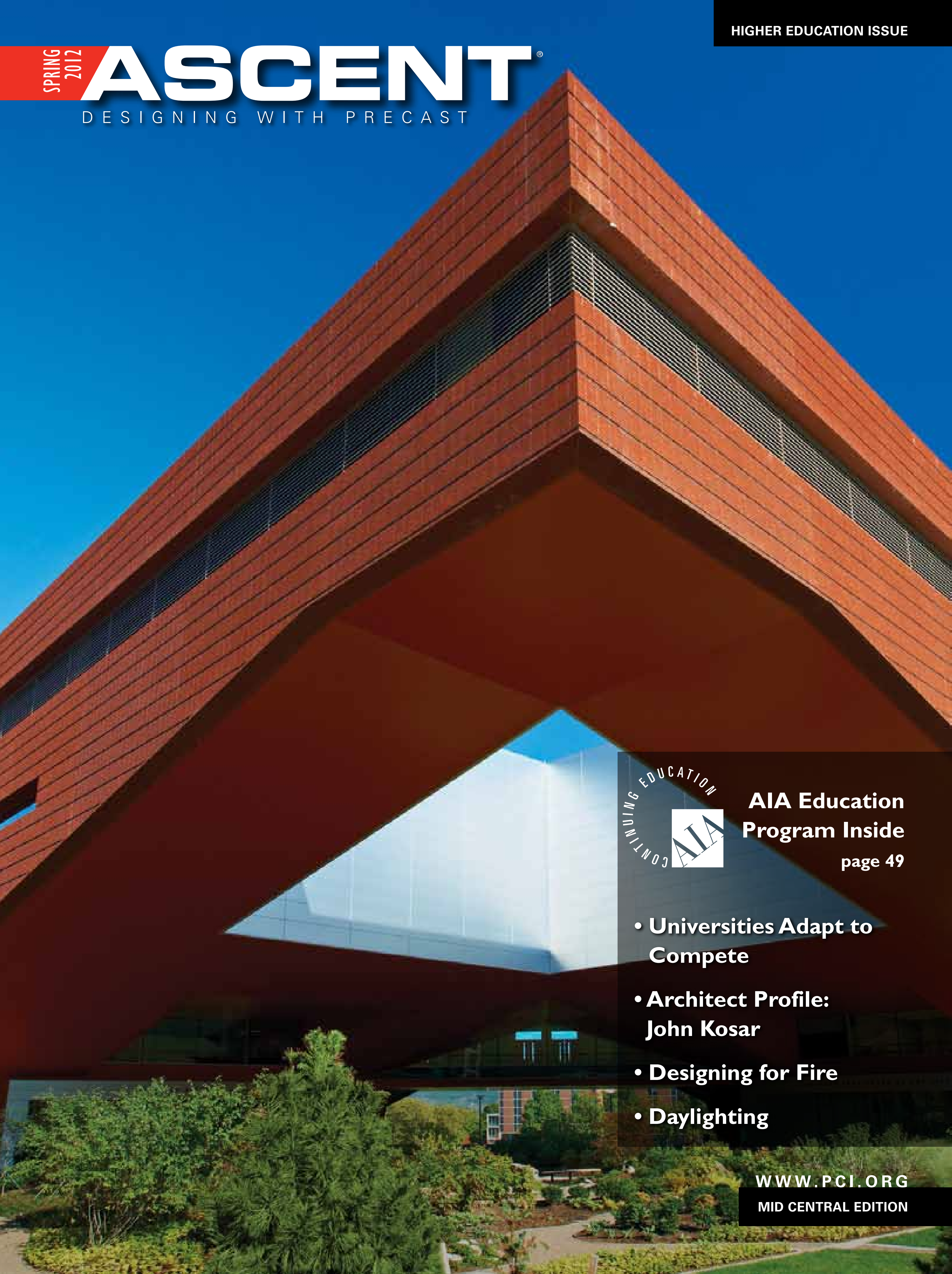

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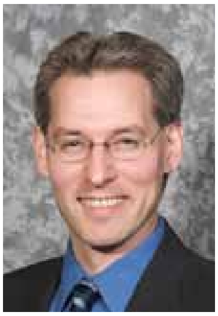
Does Sustainability Need a Paradigm Shift?



Brian Miller, P.E., LEED AP
Executive Editor
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The idea of sustainability seems to have taken root in just about every aspect of our modern-day life. Everywhere you look is some form of communication about a green attribute or a sustainability-related message. Even my children are discussing sustainability in school. The other day, as I was going to throw away some garbage, my little girl came up to me and said, "Dad, aren't you going to recycle that? We have to think about the future, you know." As you can imagine, I was very pleased to hear such a "holistic perspective" coming from my nine-year-old. The possibility that our children are being taught to view decisions and their consequences differently than we did while we were growing up is encouraging. Imagine that: A paradigm shift at age nine.

Nowhere else has sustainability been more prominent than in the construction industry. The idea of sustainability has affected the design and performance requirements for structures, as well as the products that go into them. Organizations like the United States Green Building Council (USGBC) have helped pave the way with guiding programs, such as their well-known LEED certification. The focus has mostly been on the construction process, including areas like location of a project, site impact, materials, indoor environmental quality, and energy performance. This is all a step in the right direction. However, are we overlooking something else?

In the United States alone, we have had quite a few devastating disaster "events." Some of these manifest from nature – hurricanes, tornados, floods, and fires –, while others, unfortunately, are caused directly by mankind, e.g., terrorist attacks. Of course, this is not just a challenge in the United States. These types of catastrophic events happen worldwide. The major earthquakes in Japan, Chile, and New Zealand alone have resulted in unimaginable loss. Each year in the United States, disaster-type events are responsible for billions of dollars in damage and countless loss of life. Another disturbing fact is that from the 1970s to now, the cost and amount of damage related to disasters has increased more than four times; however, the number of events has remained about the same. So why are structures becoming less resilient?

Further investigation shows that a variety of factors, such as code consolidation, changes in the project management process, economic pressures, and increased requirements on other building components (e.g., technology systems, fixtures, etc.) has placed an emphasis on decreasing overall construction costs by using less durable materials. These meet current code requirements, but we must keep in mind that building codes are a minimalistic approach, not an optimal approach. Is this approach sustainable? Is this approach really acceptable?

You may have already heard the phase "functional resilience," which seems to be growing in popularity, but what does it mean? The idea is that if a structure were exposed to an event such as an earthquake, fire, hurricane, or tornado, the structure would first remain intact, protecting those who may be seeking shelter inside. Second, the structure may be restored to its full functional capacity with minimal efforts and resources. In other words, functional resilience is the development of disaster-resistant structures that protect life and do not need to be rebuilt after an event.

It seems logical that the idea of functional resilience would be given stronger consideration in our design and construction decisions. Today, all too often we seem to focus on the "now" and not on the "tomorrow." If we want to be truly sustainable, we should consider the impact of such events. It seems silly to go through extensive efforts to create a wonderful green building only to have it devastated by an event so that we can rebuild it again later. After all, any additional cost to build functionally resilient structures is definitely less than the cost to build the structure a second time. Maybe we should have a paradigm shift of our own and think about how our decisions today affect tomorrow. After all, isn't the future a big part of what sustainability is all about?

ASCENT

On the cover: Penn State's Millennium Science Complex in Wyomissing, Pa. (see page 18)

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- If you have a project to be considered, send information to Whitney Stephens, PCI Communications Manager, (312) 428-4945, wstephens@pci.org

Erection of Finfrock's New Manufacturing Building Nears Completion

APOPKA, FLORIDA

Finfrock's new state-of-the-art manufacturing building is nearing completion. This 34,000 square foot building has a clear height of over 40 feet and will enable computer aided manufacturing technologies to be incorporated into the company's precast/prestressed concrete manufacturing facility.

Finfrock has been using StructureWorks 3D modeling software for the past several years for the design of the parking structures, mixed-use buildings, and multi-unit residential buildings it constructs. StructureWorks software operates on the SolidWorks platform and was developed and is being distributed worldwide by Finfrock.

Highly accurate laser images, automatically generated from the 3D models, will be projected directly onto the casting forms and will eliminate the need for paper drawings. Finfrock will be the first in the United States to use 3D modeling and laser technology in the manufacturing of precast/prestressed concrete structural members. The addition of laser technology will increase production capacity and productivity and will improve dimensional accuracy of products used in Finfrock's finished buildings. The new facility is expected to be complete and fully operational this spring.

Spancrete Invests in Valders Facility for WI-DOT Transportation Solutions

WAUKESHA, WISCONSIN

Spancrete®, a leader in the precast/prestressed concrete industry, is moving its entire WI-DOT transportation production line from Green Bay, Wis., to its flagship production facility in Valders, Wis.

Recently, Spancrete® made substantial investments in upgrading its 100-acre Valders operation; these investments will allow transportation production work to be accomplished with the latest advances in precast technology. Production employees from Green Bay will be transferred to Valders, maintaining Spancrete's skilled employee base.

Though the WI-DOT transportation production line is relocating, Spancrete® will continue to maintain a presence in Green Bay.

Gate Precast Produces Architectural Precast Concrete Panels for New Omni Hotel

ASHLAND CITY, TENESSEE

Gate Precast Company, one of the nation's most diversified precast concrete producers and precast design assistance consultants, has been selected to the produce and install architectural precast concrete exterior panels for the $250 million Omni Nashville Hotel.

Brasfield & Gorrie will oversee the construction for the 21-story hotel that will encompass an entire city block. HKS Hill Glazier Studio, specialists in the design of hotels and resorts, designed the 800-room hotel which will anchor the new $585 million Music City Convention Center.

The architectural precast panels will be designed in BIM and manufactured at Gate Precast's Tennessee manufacturing facility, which is 20 miles from downtown Nashville.

The project is being constructed to achieve a LEED Silver certification from the United States Green Building Council.

The Omni Nashville Hotel is expected to open in late 2013.

Heldenfels Enterprises Receives 2011 Houston Award

NEW YORK, NEW YORK

Heldenfels Enterprises has been selected for the 2011 Houston Award in the Road Building Contractors category by the U.S. Commerce Association (USCA).

The USCA "Best of Local Business" Award Program recognizes outstanding local businesses throughout the country. Each year, the USCA identifies companies that they believe have achieved exceptional marketing success in their local community and business category. These are local companies that enhance the positive image of small business through service to their customers and community.

Submit your headline news for consideration in a future issue of *Ascent* to Whitney Stephens at wstephens@pci.org.

Fabcon Hires Mark Pederson as Chief Financial Officer

SAVAGE, MINNESOTA

– Mark Peddersons

Mark Pederson has been named chief financial officer at **Fabcon**, a leading manufacturer of high-quality precast concrete solutions.

Pederson will oversee finance, accounting, treasury, risk management, contracts, information systems, and legal matters. Prior to joining Fabcon, Pederson was CFO at a large national general contractor headquartered in the Twin Cities. Pederson's work was honored in 2010 when he was a finalist for the *Minneapolis/St. Paul Business Journal's* "CFO of the Year" award in the large private company category.

Spancrete Promotes Scott Bertschinger to Vice President of HR and Risk Managament

WAUKESHA, WISCONSIN

– Scott Bertschinger

Scott Bertschinger has been promoted to vice president of human resources and risk management for **Spancrete®**.

A Spancrete® employee since 1997, Bertschinger most recently served as the company's corporate director of human resources and risk management. His promotion follows the retirement of the former head of human resources, Bill Wagner.

Bertschinger's responsibilities include all human resources, safety, insurance, and risk management activities, as well as the environmental oversight of all manufacturing and construction activities.

Bertschinger is a past chairman of the Plant Safety Committee with PCI and is also a member of the PCI Field Safety Committee. He is SPHR certified and has a bachelor's degree in urban and regional planning from the University of Wisconsin – Green Bay.

Tekla BIMsight Wins in Most Innovative Product Contest

KENNESAW, GEORGIA

Tekla BIMsight, the BIM software application for model-based construction project cooperation, was awarded Expert's Choice in the Most Innovative Product Contest at the World of Concrete exhibition in Las Vegas, Nev.

Tekla BIMsight presents the complete construction project from design to erection and site management, including all necessary building information from different construction disciplines. It makes it easy to compare data from any project participant and spot possible errors already in the design phase. The software now has a user interface optimized for tablet computers, so it is easy to take BIM to site.

Metromont Projects Take Top Honors

ATLANTA, GEORGIA

Metromont Corporation, a provider of precast building solutions, was recognized with six awards at the recent American Concrete Institute's (ACI) Georgia Chapter awards banquet in Atlanta.

Metromont received first place honors in the following categories:

- Best Parking Deck for the Athens Clarke County Parking Deck
- Best Public Works for Fort Benning Gateway
- Best Restoration for Savannah College of Art and Design's Museum of Art

Metromont also received Outstanding Achievement honors for the MacEachern High School Physical Education and Wellness Center in Power Springs, Ga., and Awards of Excellence for the LA Fitness parking deck in Atlanta and the Reynolds Street parking deck in Augusta.

Maximizing Daylighting

Attention to design techniques can improve daylight usage, reduce energy use, and improve ambience and productivity

— By Michael Ytterberg, PhD, AIA, LEED AP

Using the sun to illuminate and brighten building interiors has been a factor in the design of buildings since the beginning of time. The advent of electric lighting reduced that need, but today's focus on energy reduction and efficiency has led more owners to try to maximize daylighting techniques through every avenue possible. Designers can aid this goal if they consider daylight techniques from the beginning of the design process. But they also must be careful that, in maximizing daylight for building interiors, they don't lose control of it and allow it to become a hazard.

Historical Trends

Daylighting became a concern in the 1970s, as the first national energy crisis impacted every aspect of American life. Buildings that were designed in the 1950s and 1960s, the era of cheap and seemingly unlimited energy, became "energy hogs." Offices with deep floor plates, endless dropped ceilings, and fluorescent light fixtures ignored the benefits of natural illumination. Factories, shops, schools, and other building types were built as windowless, one-story boxes that emphasized security. These designs were led by misguided concepts that focused the attention of workers, consumers, and students on those tasks that would make them more productive.

These design trends were necessarily reconsidered as energy costs rose in the 1970s and 1980s. Incorporating free sunlight and reducing heat generated by electrical lighting became the primary ways to make a building environmentally friendly by saving energy.

Architects went to great lengths to make sunlight available to all inhabitants of residences, office buildings, hotels, and other building types. Both passive and active techniques were developed to manipulate architecturally the play of sunlight over and into buildings. A typical feature was the "light shelf," which helped pull daylight deep into facilities by shading those close to windows and reflecting light to those further away.

Large areas of glass let heat in, along with a variety of other associated problems such as drafts, energy loss, and glare. Glass walls were expensive, as were the added-on structures intended to shade and manipulate the light. And glass at the time was of limited structural value. These were just some of the challenges and advantages of the first attempts at leveraging daylighting to save energy.

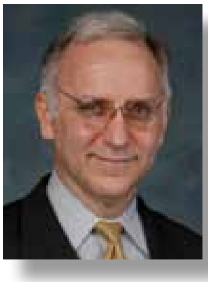
Today, a number of rating systems guide the design of energy-efficient structures. The most popular in the U.S. is LEED certification. These systems are more holistic in approach than the efforts of the 1970s and 1980s, focusing on all aspects of building and site design. They drill deeper into the design and construction process to include disposal of waste, transportation systems, and light pollution of the night sky. Daylighting, while still important, is no longer the single most important tool in the "green" toolbox.

Benefits to Daylight

There are still many significant advantages to incorporating daylighting into all building types. It has been demonstrated that people have a physiological need for sunlight, which can have an impact on mood, productivity, health, energy, and overall happiness. Though zoning and building codes around the world regulate the supply of light and air to building occupants, European countries do more to govern issues of how far workers can sit from a window and other factors. The result is the creation of buildings that, by law, have thinner sections than comparable buildings elsewhere, and which may have elaborate double-skin walls that buffer the inside from outside environments and control light, ventilation, and temperature.

The situation is different in the U.S., some of which appears to be cultural. Americans seem to prefer large, open collaborative spaces in office buildings, favoring deeper floor plates that make close proximity to windows for every building occupant difficult. More extreme weather conditions make the performance of double-skin walls more problematic here. There is always the constraint of building costs, particularly when energy has a lower cost here than in Europe. Regardless, it is possible to incorporate daylight into all building types, more so now than ever before.

New developments in glass technology mean that it can be used in a variety of ways previously unimagined. New coatings let in tremendous amounts of modulated light while restricting the ultraviolet light and transmitted heat. This is helpful in residential and office settings, as well as in industrial, retail, and hospitality settings, where temperature control can be crucial. Tinted glass and reflective coatings were once relatively



– Michael Ytterberg, PhD, AIA, LEED AP, is a principal at BLT Architects in Philadelphia.

The Hamilton Gardens social space atop Philadelphia's landmark Kimmel Center for the Performing Arts is being enclosed in a carefully crafted glass and metal enclosure that will modulate environmental conditions after its original glass-roof design proved too difficult to control. BLT Architects served as the architect and interior designer. Rendering: BLT Architects

'people have a physiological need for sunlight, which can haven an impact on mood, productivity, health, energy, and overall happiness'

crude tools to control daylight passing through glass walls that had decisive visual implications for buildings, not all of which were positive.

Shading techniques have also improved to help reduce solar heat gain, while maximizing daylighting and views. These can be incorporated directly into the design of the building, such as horizontal or vertical screens, or they can be mechanical, designed to adjust with the occupants' needs.

Daylight Hazards

Daylight exploitation must be carefully considered. Hamilton Garden, which sits on top of the Perelman Theater inside of Philadelphia's landmark Kimmel Center for the Performing Arts, was intended as a revenue-generating social space underneath the vast, signature glass barrel-vaulted roof that covers the entire building, with views both to the city beyond and into the performing arts center below. Unfortunately, an exposed space beneath a vast glass roof proved impossible to condition, and was simply too hot, bright, and noisy to be used on a regular basis, in spite of the fabulous views and magnificent architecture.

The Garden is now being enclosed in a carefully crafted glass and metal enclosure that will modulate environmental conditions to preserve the spectacular attributes of the space while making it comfortable and commodious for frequent use. Here, both sophisticated glass coatings, as well as the full range of architectural shading devices and dramatic exposed structure, were used to modulate sunlight and aurally isolate the space.

If necessary, motorized blinds and shades will be installed to move with the sun throughout the day and modulate daylight to control air and energy flow. Controls are automated and sensors can turn on artificial lighting when enough daylight is not available or off when the space is vacant. At last it will be possible to use this dramatic aerie to meet its originally intended function.

Combining Glass and Concrete

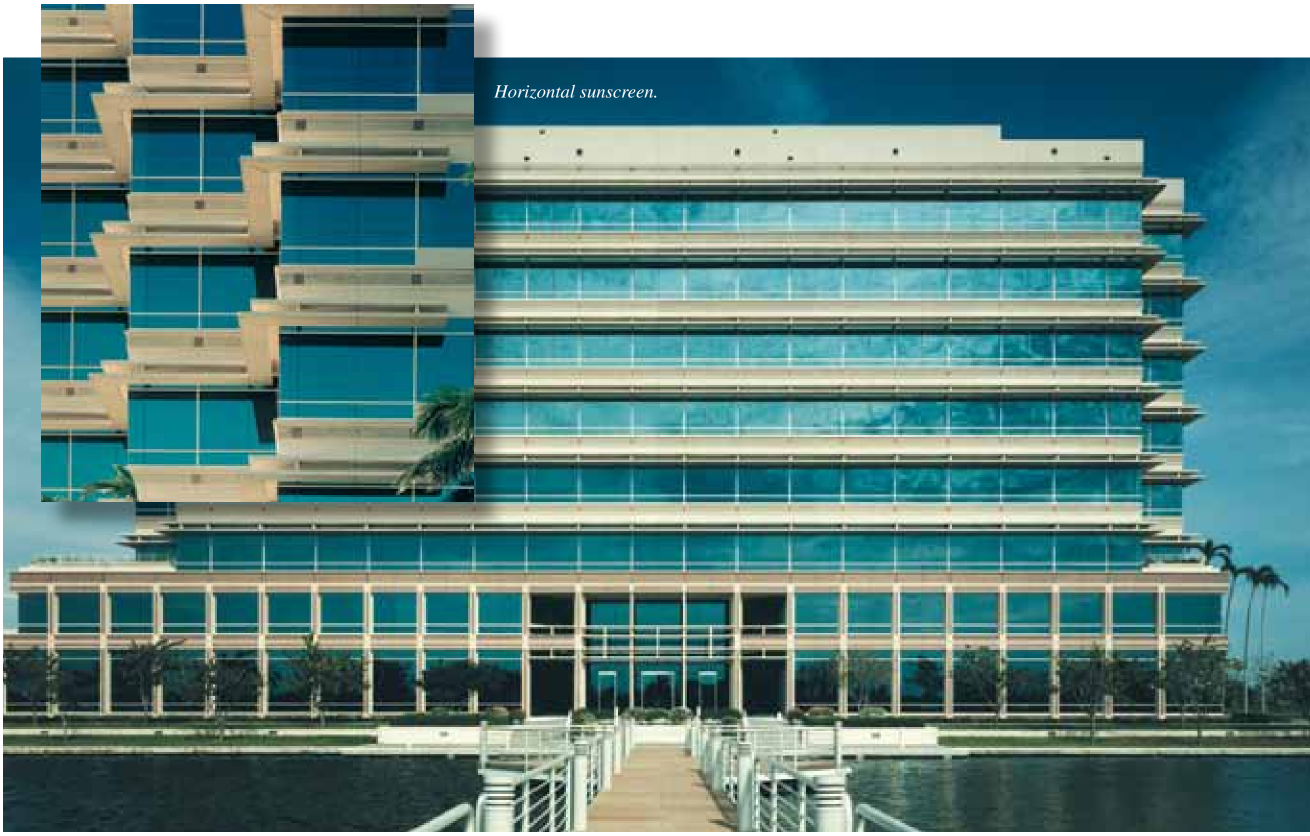
Glass facades are often seen as expressive of technology and therefore sometime desired by businesses wanting to project an image of being forward-looking and up-to-date. On the other hand, masonry and concrete buildings connote solidity, comfort, and domesticity. These two materials can be combined to create exciting projects that blend the two messages on dramatic facades.

For instance, the 32-story Symphony House condominium tower in Philadelphia features a skin of architectural precast concrete panels with a preponderance of "punched" windows and just the occasional relief of floor-to-ceiling glass where it really counts. In such residential projects, too much glass can mean too much light and exposure to heat and cold, not to mention the cost of window treatments that, at the end of the day, can cover up the glass that cost so much to include in the first place.

The carbon-fiber reinforced panels used in this project were extremely thin and lightweight yet extensively insulated, cutting down on the cost of structure and foundations while increasing energy efficiency. Manufactured under factory-controlled conditions, their use facilitated construction while also reducing waste and energy usage, providing a host of green benefits.

Specially coated glass was incorporated into the design. The windows

The 32-story Symphony House condominium tower in Philadelphia combines carbon-fiber reinforced architectural precast concrete panels with "punched" windows to leverage the use of daylight while providing sunlight control and high energy efficiency. BLT Architects served as the architect and interior designer. Photos: Michael Ytterberg.



Horizontal sunscreen.

A horizontal sunscreen is used on the Cornerstone office building in Florida to reduce solar heat gain, while permitting daylighting and views. Photo by Brian Gassel/TVS

were designed and placed to balance the simultaneous needs for privacy and spectacular views, while reducing heat loss/gain and the glare caused by sunlight. The windows were placed within a wall panel and tested as a unit to verify the highest possible standards of performance. Thus, the tools of a traditional wall, even in the context of a high-rise building, were shown to have "green" benefits and to produce an environment that is simultaneously up to date and comfortable, physically and psychologically.

Daylight For All Building Types

Daylighting techniques are also beginning to be used in building types previously considered best as totally controlled environments without any outside interference. Big-box retail stores are an example. This is not just a matter of environmental preferences but of dollars and cents. A recent experiment by Walmart showed that when skylights were added to a store, the natural light made shoppers perceive products in a more positive light and buy more. The daylighting also resulted in better employee moods and increased productivity.

Revel, a 6.3-million-square-foot beachfront resort destination opening later this year in Atlantic City will open part of its casino floor to the outside, letting natural light shine in and giving guests a view of the ocean. This is dramatized by floor-to-ceiling glass areas. The new approach relies on sophisticated glazing technology that can help modulate light and temperature, creating an experience that does not distract from the rest of the facility design.

While technology and tools have advanced to promote more daylighting in all buildings, there must still be careful design consideration for bringing the outside environment inside. All of the projects mentioned above have been built on urban, brownfield sites, in itself an important aspect of sustainable practice. In a perfect world, all buildings would be built in the middle of a field so they could be oriented to maximize exposure to the sun, with spaces oriented north, south, east, or west as appropriate for the activities housed within. However, an idyllic rural environment is not the case for most of the world's buildings.

The reality of urban and increasingly dense suburban environments means that architects must be creative in how a building is positioned and designed to get the most, best sunlight throughout the day. The architecture of daylight is still very much an art while the materials that are used have advanced with the help of science.

Each of the projects mentioned has taken into account shadows cast both into and out of the site. Each has used the appropriate techniques to modulate the environment of specific functions wherever the functional arrangement and site conditions allowed them to be placed, keeping out negative environmental impacts while accepting and accentuating the positive.

Daylighting is a powerful tool in design, one that can make buildings more pleasurable and more efficient places to live, work, and play. This is as true now as when people first began to build. Moreover, techniques first developed in recent years in response to the realization that nonrenewable energy sources have a steadily increasing cost and, ultimately, a limited life, will become the standard by which future architecture will be built, ensuring an efficient, productive, and pleasurable built environment for human lives. ■

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

Universities Adapt to Compete

Designers need to help universities adapt to new global demands, teaching methods, and technologies to ensure America retains its lead in innovation

— By Robert Powers, AIA, LEED AP, HOK

To compete in today's global economy, innovation is crucial. America's commitment to innovation and technology has enabled us to lead the world in economic development, thanks in part to the quality of our educational system. Today, that leadership is being challenged, requiring universities to respond with better methods, better technologies and better facilities. Architects have a huge opportunity and responsibility to assist our clients in meeting these challenges.

The truth is that America no longer leads the world in scholastic achievement. A sobering statistic to note is that China and India have more honor students than the U.S. has students[1]. The outsourcing of manufacturing jobs could be followed by an outsourcing of intellectual capital if we are not careful. The United States' future success will be tied to our ability to innovate. America's colleges and universities provide the best environments to shape the next generation of leaders who will help us meet that challenge.

However, in their mission to help America stay competitive in the world market, universities face great obstacles. For instance, state schools increasingly compete among each other for limited funds. In Missouri, the governor recently announced a $12^1/_2$ percent cut in state funding to the university system, while the California State University system has lost 27 percent of its funding since 2010. This has forced severe cutbacks at a time when educational resources should be increasing. Investing in our education system is vital in order to continuously raise the bar. Instead, competition among colleges is fierce, not only for recruiting students, but for funding as well.

– Robert Powers, AIA, LEED AP is an architect with HOK, St Louis, MO.

So what is needed to compete in the education market? Great faculties are a must, as are facilities that support both current technology and tomorrow's unknowns. Creating an environment in which both students and faculty are excited to live and learn keeps them engaged with one another and focused on learning. These qualities can set a campus apart from its competitors.

Corporations have realized for years that to attract and retain the best employees, they need to provide a healthy, attractive work environment with a certain level of amenities. Universities wanting to retain the best faculty and students need to provide a stimulating environment equipped with the tools necessary to compete in today's world.

Keeping Current

Anyone who believes they can predict tomorrow's technology is misleading themselves. Not that long ago, a professor told me he could not imagine a time when every student would bring their own personal laptop to class. "Computers are just too expensive," he said. Today, we are quickly moving past laptops to tablets and other portable (and inexpensive) devices.

Along with the hardware, new software has evolved that enables students to learn at their own pace. New technology has allowed students to stay connected and collaborate with fellow students and teachers across the globe. Distance Learning has given students virtual access to thought leaders in their field of study wherever they are located. One question designers (or universities) must answer is whether or not this new technology is relegated to a few special classrooms or if it is embedded throughout the building?

Both curricula and space will need to change to accommodate these new methods of learning. Think about how the role of the architect and the way we practice our profession has changed since you began your career. There is a greater emphasis on collaboration. Building design now often represents only a portion of the services we provide to our clients. Our academic buildings need to accommodate future unknown technologies and methods of learning that reflect the business world.

I suggest this means we need to design for the general; not the specific. When possible, design more generic and flexible space and less custom single use environments.

Inside The Classroom

The nature of education, how we learn and what we learn, has changed greatly over the past several years. Historically, students were taught by teachers standing at the front of the class and lecturing to the students. "Chalk and Talk". The chalk and blackboard were replaced with projectors, which were replaced by smartboards, but until recently the same learning process endured.

Today there is a greater emphasis on group learning. We better understand the importance of critical thinking and collaboration over rote memorization. "Chalk and Talk" fills only a small portion of class time. Students working in smaller groups and learning from one another has become the norm. This transformation is not only occurring at the university level, but also in elementary and secondary schools across the nation.

The scale and proportions of today's classroom need to adjust to accommodate the different styles of learning. This translates to larger structural bays and greater floor-to-floor heights to accommodate technology.

This will create a great need for renovation and revamping of existing spaces. Today's classrooms simply do not fit inside many of the older buildings on campus. Fixed seating with tablet arms has given way to more flexible furniture systems that allow classrooms to take on multiple arrangements. But the rooms have to accommodate those arrangements, and many currently do not.

An atrium at the University of Dayton provides a visually stimulating environment for people to gather and continue the learning process outside the classroom.

Outside The Classroom

Changes also must occur outside of the classroom to meet these new needs. David Thornburg may have summed it up best in a paper titled, "2020 Vision for the Future of Education" when he said, "In addition to the basic skills of literacy and numeracy, every learner must also master the 'three C's:' Communication, Collaboration, and Creative Problem Solving." These skills are not necessarily best learned in the classroom. Learning must continue outside of the classroom.

Classrooms and corridors often fill the floor plans of many older academic buildings without relief. Walking through these corridors can become an obstacle course of stretched-out legs and backpacks as students have nowhere else to gather. These layouts make it difficult for students and faculty to continue discussions beyond the allotted classroom time.

Multidisciplinary programs often do not foster the casual interactions between students and faculty of the various departments that can lead to new insights and collaborations. Instead of just corridors, the circulation space should be similar to a well-designed city with spaces for people to gather, access to food and drink, and a visually stimulating environment.

One of my many memories from architecture school several years ago at Washington University in St. Louis centers on the main staircase in Givens Hall. A dual staircase on either side of the main entrance led to a generous landing with a large operable window above the entry.

This landing was more than just a means to reach the second floor studios—the space became prime real estate and a preferred hangout space. In the days before social media, students were able to monitor and connect with fellow classmates entering and leaving the building. Centrally located, the landing was a magnet for informal interactions between both students and faculty.

These opportunities for continued discourse outside the classroom are at the heart of what I feel represents the very best of the academic experience.

Students learn in many ways. Spaces should be provided for the informal group-study session just prior to test time as well as for more individual and focused thinking, where real understanding of a subject matter occurs. Well-designed buildings need to accommodate both. Thinking back to the staircase at Givens Hall, this can simply mean a slightly more generous space strategically located within the plan.

The learning process should be celebrated and put on display. Often we find really cool aspects of the program hidden away in a remote lab or classroom. Placing these elements of the program prominently along primary circulation paths for everyone to experience helps to build excitement about the curriculum and provide a better understanding of the school's mission to students and visitors.

Thinking again back to my days in architecture school, many long hours were spent in studio. Back then, we had to head to the student union or leave campus for food and drink. Once a student left the building, the focus on learning was lost. Today, many campuses are including some form of food service inside the academic buildings. These features are natural magnets for bringing people together and keeping the students immersed in the learning environment.

Providing this type of environment can create a budget challenge. If the initial program reflects only the classroom and corridors thinking, the additional space necessary to create a great learning environment can effect

The four-story, 100,000 sq. ft. Anheuser-Busch Natural Resources Building's precast concrete façade houses offices, laboratories, and a 500 seat auditorium at the University of Missouri – Columbia.

the budget. Often, budgets are fixed before this level of development occurs. Try to quantify your space requirements early in the project, ideally during the programming phase, to include the area needed to avoid budget shortfalls.

Several strategies exist that will allow the project to absorb some amount of additional square footage. Simplifying the design of a space often provides greater flexibility over the long run along with lower cost. Specifying less expensive materials that do not compromise durability and maintenance can lead to further reductions.

The Building Façade

One of the most challenging and interesting aspects of designing academic facilities is the need to have an attitude about and relationship with the surrounding campus environment. One approach is to match the vocabulary and materials of the adjacent buildings on campus. This provides unity to the campus and works well in many cases.

Another approach is to respond with a façade that is respectful of the existing campus environment while acceding to today's demand for more efficient and sustainable buildings. Today's buildings are often trying to convey a different message than the more traditional ivy-covered façades of previous years. The more extensive use of glass we see in many modern academic facilities helps meet the need for increased daylighting, often a key component of sustainable design, as well as communicates a more open and accessible environment to the community.

Limestone and brick are two materials that are found on many college campuses. The University of Missouri at Columbia, where HOK has completed several projects over the years, has two distinct districts - the red campus and the white campus. The original historic buildings of the red campus are defined by the use of red brick, while the use of limestone defines the white campus that developed as the university expanded.

Precast Concrete's Versatility

Precast concrete allows us to economically respond to both of these materials, limestone and brick. Precast concrete can take on a number of textures and colors that either closely matches an existing nearby limestone façade or create a new interpretation that expresses a campus's intent on moving into the 21st century. The use of thin or half bricks on a precast panel can simulate the scale and texture of a hand-laid brick façade while improving the construction schedule, overall durability, and budget.

New technologies and manufacturing methods have increased the efficiency of precast concrete and opened exciting design opportunities. The development of Ultra High Performance Concrete (UHPC) is one of these opportunities. It is extremely durable and offers strengths ranging up to 22,000 psi, allowing the use of thinner panels measuring approximately 2 inches thick or about $^1/_3$ the thickness of a typical precast panel. This translates to less material needed on the job and less fuel consumed in transport.

UHPC can further extend savings to both foundations and superstructures due to reduced loads. Energy efficiency and moisture management are two of the most crucial elements of façade design today. Rain-screen construction is one method that strives to resolve these issues by providing a continuous uninterrupted air barrier with insulation outside the stud-wall cavity. Typically constructed with lighter weight materials, UHPC makes precast a feasible and durable choice for rain screen façades. Precast concrete sandwich wall panels can also provide continuous insulation within the panel, contributing to a very efficient envelope.

These technologies allow architects to provide their clients with a building façade that will last for years with very low maintenance requirements.

Helping The Process

Chancellors and boards of trustees have to make tough decisions about allocating funding in today's economy. As architects, we can help ease the decision-making process through smart design. Design that creates the types of environments that stimulate both students and faculty adds value to the academic program. Buildings that can adapt over time without expensive renovations or compromise are great assets that help universities stay ahead of the curve and able to embrace new technologies.

By selecting materials that reduce first cost and do not burden the facilities' staffs with excessive maintenance and repairs, funding can be freed up for future opportunities. The design and cost flexibility of precast concrete can help create the façades that will house the great learning environments of the future.

Reference

1. "Does the U.S. realize it's in competition?" by Robert J. Herbold, http://www.case.edu/magazine/springsummer2010/competition.html ■

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

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Precast sections from Glen-Gery define the look and soundness of the Millennium Science Complex on Penn State University's campus.

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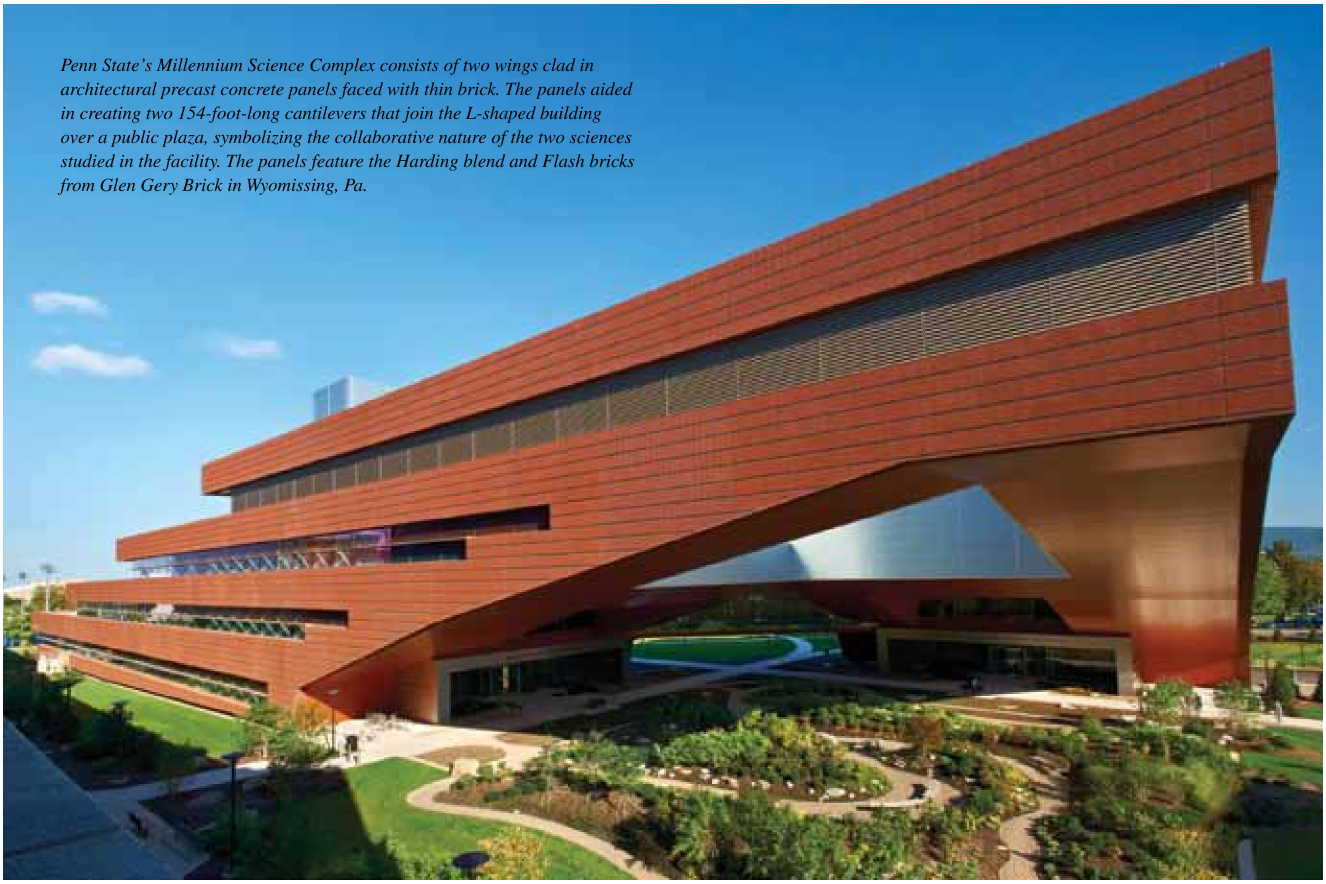
Precast and Innovation Combine To Meet Schools' Variety of Needs

Structural and architectural precast concrete components help colleges and universities meet the diversity of requirements of their users while ensuring a complementary look for the campus

— Craig A. Shutt

Universities operate as their own small cities, with diverse programmatic needs for their variety of users in a range of building types. These include classrooms, offices, residential units, parking structures, community-gathering facilities, recreational centers, theaters, stadiums, and even highly specialized laboratories. Meeting the requirements for these buildings—some of which may combine two or more functions—creates challenges. Their design and construction can become even more daunting when the new buildings must fit seamlessly into an existing campus aesthetic, be constructed without disrupting activities around them, and be ready for the new semester when students arrive back at school.

Many administrators, designers, and contractors are finding that precast concrete components can help them achieve their goals in a cost-efficient way. Total precast concrete structural solutions offer a variety of benefits in speed of construction, quality control, elimination of site congestion, sound and vibration control, fire resistance, and other areas. Architectural precast concrete panels offer many of these benefits, as well



Penn State's Millennium Science Complex consists of two wings clad in architectural precast concrete panels faced with thin brick. The panels aided in creating two 154-foot-long cantilevers that join the L-shaped building over a public plaza, symbolizing the collaborative nature of the two sciences studied in the facility. The panels feature the Harding blend and Flash bricks from Glen Gery Brick in Wyomissing, Pa.

as the plasticity to blend with any existing aesthetic style, from historic to contemporary. Precast concrete also contributes to an energy efficient envelope system, which has become increasingly important, especially as sustainable design requirements continue to increase.

The material's use is growing as well because developers familiar with precast concrete's benefits from other projects are becoming involved in more higher education projects as states encourage public-private partnerships.

The following examples show some of the ways universities are taking advantage of precast concrete's many benefits to achieve multiple goals with a range of building types.

PSU Science Center – Cantilevers Join Science Departments

The Millennium Science Complex is located on the campus of Penn State University in University Park, Pa. It consists of two wings, one for the Huck Institute of the Life Sciences and one for the Material Research Institute, both containing specialized laboratories and research facilities. The multiple opportunities for the two sciences to collaborate on projects are epitomized by the two 154-foot-long cantilevers from each wing of the structure that join the L-shaped building over a public plaza. Enhancing this unique design is the use of precast concrete architectural panels embedded with brick on its facade.

"The goal was to create a facility that would provide an individual identity for both laboratory sciences while creating opportunities for collaboration by housing them in the same building," explains David Rolland, project director at RV Architects. "The architectural solution with the monumental conjoined cantilevers from each wing reinforces the promise of that collaboration."

Although the two wings have unique and separate programs, the building provides an opportunity to foster collaboration between these scientific endeavors. The programs were joined with a cantilevered connection, and the design team conferred with structural engineers about how the concept could successfully

PROJECT SPOTLIGHT

Penn State Millennium Science Center

Location: *University Park, Pa.*

Project Type: *Life sciences and Material sciences laboratories*

Size: *292,100 square feet*

Designer: *RV Architects, New York*

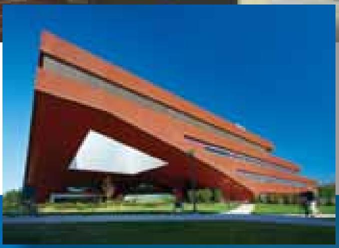
Owner: *Pennsylvania State University*

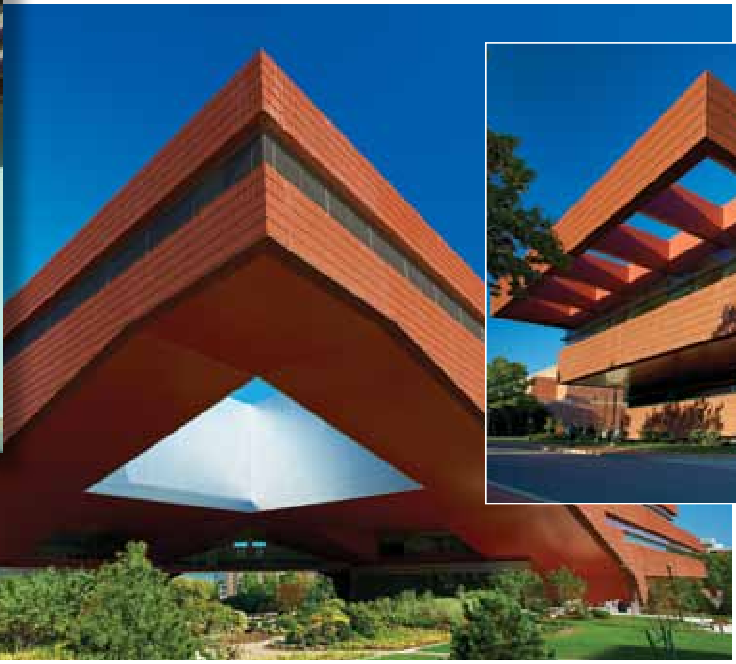
Structural Engineer: *Thornton Tomasetti Engineers, Newark, N.J.*

Construction Manager: *The Whiting-Turner Contracting Co., Allentown, Pa.*

PCI-Certified Precaster: *High Concrete Group LLC, Denver, Pa.*

Precast Components: *345 architectural spandrel panels embedded with brick.*





Photos courtesy of Nathan Cox

balance aesthetic, structural, and functional needs. The cantilever forms an open-air courtyard below and projects away from two roads that the wings front, stepping back until the upper level extends outward to join the other wing.

The cantilever was formed using steel trusses with precast concrete cladding panels that contained an embedded brick veneer. The panels are 22 feet long and vary in height from 8 to 12 feet. They not only provided the aesthetically pleasing and complementary look that was desired for the overall building but helped dampen the cantilever's potential vibrations by providing mass at the perimeter. High Concrete Group LLC provided the precast concrete components.

'The architectural solution with the monumental conjoined cantilevers from each wing reinforces the promise of collaboration.'

Precast Concrete Aids Dampening

"The mass of the concrete helps dampen the structure-borne vibration, which is critical for the building's specialized laboratories," Rowland explains. These spaces include clean rooms, electron-microscope labs, and vivariums where experiments could be affected by minute vibrations. Specialists studied the potential for vibration caused by the HVAC equipment located on the fourth level of the cantilever and determined that the concrete mass on the exterior precast panels would assist the steel frame and concrete shear to control the transmission of low-frequency vibration.

The bricks were selected to complement the "Penn State brick," used throughout the campus to create a coherent palette that can dominate the other brick colors that had been used over the years. The facades of the Millennium Science Complex consist of a mixture of deep reddish bricks with intermittent "flash" bricks distinguished by a charcoal-burnt hue resulting from a longer firing process. The design team segregated these bricks within the panels while retaining similar proportions for the bricks of mixed shades used elsewhere on campus.

The flash brick was used in a reveal pattern spaced every two feet up the height of the building, which emphasized the façade's scale and strengthened the horizontal lines of the building form as it steps up through four levels, Rolland explains. The stepping away of the building from the adjacent streets established a human scale with the streetscape and allowed five green-terraces to be built at various levels, keeping the sensitive laboratories furthest from the ground vibration caused by vehicular traffic.

The architect chose to use an approximately one-inch thick, thin-brick due to its preferred surface quality, which better reflected the local rusticated masonry of traditional structures. Rolland says, "The advantages offered by the precast concrete panelized construction were especially helpful in creating the cantilever. Many large pieces could be erected in a single day with a higher level of quality control, as opposed to trying to lay brick in a traditional method with scaffolding." This was particularly important due to the stack-bond pattern of Norman-style bricks, which accentuate the close tolerances at both the vertical and horizontal joints

"We made a number of trips to the precaster's plant to discuss the approaches to quality control," Rolland says. "High Concrete put a huge effort into ensuring the panels were tight on the tolerances, precise on the alignment, and cleaned of mortar slip."

The process required submission and revision of multiple small samples, the creation of a full-scale mock-up, and multiple factory reviews of panels before they were shipped to the project site, he says. "The contractor was challenged to produce a product that met our expectations. Through this process, he produced a product that we are all proud to have installed on this important research facility."

Precast Creates Window Depth

The precast concrete design also helped create a feeling of depth within the exterior enclosure by the use of C-shaped panels with returns around windows allowing the continuous horizontal glazing on each level to be recessed, with the precast panels serving as the spandrel and providing shading for the glazing. "The profile of the façade is a key reason we specified precast concrete panels for this application, as we could not have achieved that effect through traditional masonry construction."

Between each two levels of precast concrete panels, two lites of glass were split horizontally by an exterior shading device that controls solar heat gain and glare while adding an aesthetic feature. The lower vision lite wraps around the entire building, providing views to the exterior, while the upper lite is fritted and improves daylighting. A system of metal panels and storefront glazing encloses the building around the landscaped exterior courtyard.

The brick-faced panels consist of 6 inches of concrete supporting the brick, backed with 4 inches of rigid insulation and a vapor barrier. In total, 345 precast panels were fabricated, trucked to the site, and erected from a staging area near the building.

Construction was completed in two phases, with foundations and other site prep completed while precast concrete components were cast. Then the steel framework was erected and the precast panels were attached.

The most challenging portion of the work was erecting and linking the cantilevered wings at their apex. Cranes had to be placed on either side of the wings, with panels hung on the facades at the same rate so the trusses could deflect together simultaneously. In-place adjustment of the panels was considered and designed by the precast concrete contractor to allow tolerances to be met through the fine-tuning of panel alignment as the cantilever deflected.

The precast concrete panels contributed to the project's sustainable goals by enhancing energy efficiency with their thermal mass, being composed partially of recycled materials, and producing the materials within the region. Another key element in the complex's sustainability efforts is the use of extensive green roofs on both building wings. They serve as a storm-water control system, reduce energy loads due to their insulation value, extend the life of the roof, and filter pollutants and greenhouse gases. The project has applied for LEED Certification.

In addition, more than 90% of construction waste was diverted from disposal at a landfill and at least 10% of materials used in construction were from recycled content, including the precast concrete. Sustainably harvested wood was used, and 10% of the materials were regionally sourced, again including the precast concrete components.

University of New Mexico Parking – Offsets its Energy Use

As the University of New Mexico in Albuquerque has grown, surface parking lots have been sacrificed to allow new buildings to meet the variety of on-campus needs. As a result, the reduction in campus parking spaces was creating a major shortfall, requiring a quick solution. The Yale Parking Structure was recently constructed to add 797 spaces in a six-level design that was completed rapidly using a total precast concrete structural solution.

The 288,000-square-foot structure is located on the corner of a busy intersection of the campus and was designed with ease of access in mind for vehicles, pedestrians, and bicycles, explains Jarrod Cline, project architect at Dekker Perich Sabatini Architects.

The site created construction challenges, as would be expected on a campus requiring more parking to alleviate congestion. The site is surrounded by existing buildings on three sides, including two listed on the National Register of Historic Places. As a result, the design had to minimize impact on these structures while also paying homage to their traditional appearance. Construction was further complicated by a fall in topography of approximately 22 feet from one side of the site to the other and the school's desire to have the project ready to open for the new semester, which created a tight time frame.

The precast concrete structural system consists of double tees, load- and nonload-bearing spandrels, "lite" walls (shear walls with punched openings), beams, columns, stairs and landings, stair-wall panels, and grade beams. The system was selected for several reasons, Cline says. These included its ease of constructability and the high level of quality that could be provided. The capability for off-site fabrication aided this, both by control-

The new Yale Parking Structure on the University of New Mexico's campus lies adjacent to several buildings on the National Register of Historic Places, requiring the parking facility pay homage to that aesthetic while providing desperately needed parking space. A total precast concrete structural system helped it meet all of its aesthetic, functional, construction, and budget goals.

Photos courtesy of Dekker Perich Sabatini Architects

PROJECT SPOTLIGHT

University of New Mexico Yale Parking Structure

Location: *Albuquerque, N.M.*

Project Type: *Parking structure*

Size: *287,000 square feet*

Cost: *$13 million*

Designer/Engineer: *Dekker Perich Sabatini Architects, Albuquerque, N.M.*

Owner: *University of New Mexico, Albuquerque, N.M.*

Contractor: *McCarthy Building Companies, Tempe, Ariz.*

PCI-Certified Precaster: *Coreslab Structures (Albuquerque), Albuquerque, N.M.*

Precast Specialty Engineer: *Salmons P.C., Albuquerque, N.M.*

Erector: *Gibbons Erectors, Englewood, Colo.*

Precast Components: *Double tees, load- and nonload-bearing spandrels, lite walls, beams, columns, stairs and landings, stair-wall panels, and grade beams.*

ling the casting process and by minimizing congestion on the site during construction. Coreslab Structures (Albuquerque) Inc. supplied the precast concrete components.

The design features long-span construction, with a framing system of pre-topped double tees spanning 64 feet to beams, columns, and litewalls. "This design allowed parking spaces on each side of a center driving aisle, helping patrons feel more secure in the long-span areas because they're so open and well lit," he explains.

The structure's exterior was designed to fit into and respond to its surrounding context. "The predominant finish material in the area is tan-plaster stucco," Cline explains. To blend with context, the precast spandrel panels were designed with a tan integral color and a light sandblasted texture.

To highlight the pedestrian access points and frame the structure, corner stair towers were coated with a semi-transparent soy-based stain that was applied to the precast concrete panels once they were erected. "The reddish-orange color of the stair towers adds a new way-finding device on the campus and gives some life to the building," he notes. "It creates a dramatic contrast while also complementing the medical campus across the street."

To break up the horizontal nature of the parking structure between stair towers, vertical stainless-steel mesh panels were hung from the structure's face. "The mesh panels create the appearance of small, rectangular openings in the façade between them, breaking up the long, horizontal openings, helping it respond better to the adjacent buildings," Cline explains. At night, the lighting makes the mesh more transparent, bringing more visibility into the structure and creating a safer environment. The mesh panels were attached to the spandrel panels with a tension system, using brackets at each level to secure the mesh to the panel face.

The structure's east side deviates from the other three due to the adjacent chilled-water plant that discharges mist. To eliminate the concern of mist falling on cars, a wall with an oversized polycarbonate louver was installed. The louver also allows fresh air to move freely though the structure as well. A car fire that erupted shortly after the structure was completed gave an unintended test of the system, which dispersed the smoke smoothly.

Erection was complicated by a curfew placed on the precast deliveries by the city to avoid conflicts with rush-hour traffic, requiring all components to be delivered in early morning or mid-day. Foundations were poured in a scheduled order to allow the crane and delivery trucks to maneuver around the jobsite without interference.

> Precast concrete was selected for its ease of constructability and its high level of quality.

The components were delivered to the site in a specific order using just-in-time delivery to alleviate congestion. They were erected quickly, using a hydraulic crawler crane, which had limited maneuverability on the site. Close communication among contractor, precast plant, and erector ensured the fast-track schedule was met.

The construction process also was aided by the use of precast concrete stairs throughout the project, Cline notes. They were cast and erected as every level was built, speeding installation and allowing them to be used throughout the remainder of construction. The stairs were cantilevered in some areas, creating a "clean and modern look" that fit with the overall design statement, he says.

Incorporated into the design of the upper level of the structure is a steel canopy that not only provides shade but supports a 180-KW photovoltaic system consisting of 820 modules purchased from a local supplier. The installation offsets the energy demand load of the parking structure. The canopy's saw-tooth design allows for maximum solar orientation, while the clear span provided over the parking bays minimizes vehicle obstructions.

"The installation is very visual and provides an obvious indication of the commitment UNM is making to sustainability within their projects," Cline says. The array was provided as an additive alternate, and it was approved once it became apparent that the project was going to come in under budget (by about $800,000 under the construction estimate).

The structure's master plan also provided accommodations for growth, taking into account future development to the north with an academic/commercial building liner, and to the south, where provisions were made for expanding academic functions by replacing current low-density buildings.

LSU Basketball Arena – Precast that Cleans Itself

Designers for an addition onto the existing basketball practice facility at Louisiana State University in Baton Rouge faced a key challenge: The existing arena was a distinctive elliptical structure with no natural locations to create an addition without disrupting the building's flow. The design and construction also had to be completed in only 18 months to ensure it was ready for practices before the new season. To accomplish these goals, the designers used several precast concrete components, including architectural panels and stadium stair riser units.

"The real challenge was creating an addition to this iconic structure, which in no way lent itself to expansion," says Thomas Holden, principal at Holden Architects in Baton Rouge. The structure, built in the 1970s of cast-in-place concrete, features formidable architectural elements, especially protruding bent columns that extend to the roof to "grab" it as if it were a basketball. "We had to break that geometry with an addition that came off the rear of the building without breaking the symmetry."

To achieve this, the designers eliminated two massive pedestrian ramps and selected architectural precast concrete panels to clad the new rectangular facility, helping to convey the same mass and appearance as the original. "We use the same forms as the original design has to replicate that feel." Precast was chosen due to its cost efficiencies in casting the components, the speed with which it could be cast and erected to meet the schedule, and the aesthetics it could provide, he explains.

The rectangular addition features similar column bents that "grip" the roofline and uses the same coloring as the original building to blend with the structure. The 58,960-square-foot addition features two new practice courts for the men's and women's teams,

Photos courtesy of Holden Architects

Creating an addition to the iconic basketball practice facility at Louisiana State University was achieved by replacing large pedestrian ramps with a rectangular entrance in the same style as the existing facility. The addition was clad with architectural precast concrete panels and fronted by precast concrete stadium-stair components to create an efficient entry. The panels include TX Active, a self-cleaning photocatalytic titanium dioxide admixture from Essroc, to reduce long-term maintenance needs.

PROJECT SPOTLIGHT

Louisiana State University Basketball Practice Facility

Location: *Baton Rouge, La.*

Project Type: *Sports facility*

Size: *58,960 square feet*

Cost: *$15 million*

Designer: *Holden Architects, Baton Rouge, La.*

Owner: *LSU Athletic Department, Baton Rouge, La.*

Structural Engineer: *AST, Baton Rouge, La.*

Contractor: *Guy Hopkins Construction, Baton Rouge, La.*

PCI-Certified Precaster (stairs): *Gate Precast Co., Ashland City, Tenn.*

PCI-Certified Precaster (panels): *Gate Precast Co., Monroeville, Ala.*

Precast Specialty Engineer: *PTAC, Monroeville, Ala.*

Precast Components: *Architectural panels, column covers, and stairs.*

storage, restrooms, and a two-story entry lobby with display space for trophies. A grand staircase ascends to a multi-function/banquet room. Also included are locker rooms, viewing rooms, lounges, and meeting rooms.

Stairs Create Efficient Entry

The entry stairs feature precast concrete stadium-seating components, including raker beams and risers. "They required a fraction of the space occupied by the original ramps," Holden says. They also were quick to erect as the project was constructed.

The erection was complicated by the constricted site, due to the adjacent football stadium and the ongoing campus activities. The components were delivered on flat-bed trucks to a staging area on the other side of campus. They were then called to the site in sequential order, where the crane picked the pieces from the truck and erected them directly.

The precast concrete panels provided an additional benefit not available to the original. Due to the area's high level of humidity, north-facing walls often have mildew problems, creating black stains—and the original arena is no exception. To avoid that aesthetic problem and lower long-term maintenance needs, designers specified a self-cleaning photocatalytic titanium dioxide admixture, its first use on a university campus in the United States. The coating provides a bright-white color and, when exposed to UV rays, the titanium dioxide acts as a catalyst helping to break down organic compounds and allowing them to be easily washed from the surface by rain. This also helps prevent mildew from forming.

PROJECT SPOTLIGHT

Central Piedmont Community College Student Parking Structure

Location: *Charlotte, N.C.*

Project Type: *Parking structure (with office space)*

Size: *326,527 square feet*

Cost: *$16.2 million*

Designer: *Neighboring Concepts, Charlotte, N.C. in collaboration with ADW Architects, Charlotte, N.C.*

Structural Engineer: *Carl Walker Inc., Charlotte, N.C.*

Owner: *Central Piedmont Community College, Charlotte, N.C.*

Contractor: *Rodgers Builders, Charlotte, N.C.*

PCI-Certified Precaster: *Metromont USA, Charlotte, N.C.*

Precast Components: *Girders, double tees, inverted tee beams, columns, lite walls, shear walls, architectural spandrels, wall panels, flat slabs.*

Photos courtesy of Carl Walker Inc.

The new eight-level, 1,002-car parking structure at Central Piedmont Community College features a total-precast concrete structural solution. Two concrete pigments, one between bricks and one on larger portions, sometimes in the same panels, were used to achieve the appearance that the designers sought.

"The additive increased the cost of the precast panel fabrication, but university administrators readily accepted it because of the savings they will obtain in lower long-term maintenance costs," Holden explains. The building, completed in late 2010, has had no problems and is guaranteed by the admixture company against any mildew on its façade throughout its life.

The result is a facility that meets all of the programmatic needs while achieving the aesthetic goals. "We needed an upscale presentation with contemporary finishes that would endure and resist the impact of our adverse climate," he explains. In addition, the precast concrete approach cut more than 12 months from the estimated construction schedule for cast-in-place concrete and saved an estimated $500,000 in foundation costs.

Community College Parking – Blends in While Making a Statement

Located in the heart of Uptown Charlotte, N.C., Central Piedmont Community College was in dire need of additional student parking facilities. But to fit a new structure into a campus surrounded by an urban, historic environment required careful attention to aesthetics and construction approach.

To meet these needs, the new eight-level, 1,002-car facility features a total-precast concrete structural solution consisting of double tees, inverted tee beams, columns, shear walls, stairs, and architectural wall panels finished with embedded thin brick. Metromont USA in Charlotte., N.C., provided the precast concrete components.

Because of the relatively small area available, the structure was confined to two parking bays in width, says Joey Rowland, vice president at Carl Walker Inc. in Charlotte. "At two bays wide with 1000 spaces, the structure had to be eight tiers in height" he says. "The key challenge was to ensure the structure didn't 'read' as a tall project."

The parking structure had to make a strong, individual statement but also blend with its urban location.

At the same time, the project serves as a landmark for the campus, and its location adjacent to a Depression-era football stadium played a role in its design. "The parking structure serves as a 'bookend' for the college," explains Luis Tochiki, a partner at architectural firm Neighboring Concepts. "It had to make a strong, individual statement but also blends with its urban location and its brick and stone surroundings in the heart of the city."

Thin Brick Matches Nearby Campus Buildings

Most of the spandrels, typically eight inches thick and 6 feet 8 inches high, feature embedded thin brick that complements adjacent buildings in the area, says Tochiki. "We were fortunate to find a blend of colors and textures for our brick that matched the existing hand-laid bricks in other buildings."

The bricks are set into a form with a darker concrete mix securing them, simulating the look of mortar. In other portions of the panels, lighter colors were used and sandblasted, emulating a buff-colored limestone. "Combining the two mixes in one panel created a challenge for the precaster, but it was critical to use the darker mix between bricks," explains Rowland. "If there had been a buff-colored mix there, the contrast would have distorted the visual appearance of the bricks. But the precaster did it, and it looks very authentic."

In the buff-colored portions, various aggregates were combined in the appropriate proportions, and a light sandblasting was applied, to create the desired color and texture. "The coloring was a true collaboration from design through construction, and it worked perfectly," says Tochiki.

The structure is anchored by a tall stair tower on a key intersection that faces the campus. The tower is clad in brick-faced precast concrete panels and topped by a limestone-like bell-tower level. It features decorative Art Deco elements overlapping with the lower brick that reflect the adjacent stadium's design. Decorative limestone-colored accents frame openings that resemble windows, adding horizontal elements to the vertical columns of brick and disguising the intent of the structure.

The panels between columns were set back two feet four inches from the exterior face of the columns providing greater visual interest than a more typical eight-inch setback would have provided. Tochiki notes "The increased depth also helped break down the large scale of the building, allowing it to relate to the smaller structures around it."

Precast Offers Quality, Durability

Several factors contributed to the selection of the precast concrete structural system in addition to its ability to achieve the proper aesthetics. "Precast concrete has inherent quality and durability, due in part to the components being produced in a controlled environment," Rowland explains. "Durability is critical in every project we design, so we use every reasonable technique to ensure a durable and low-maintenance facility." To that end, the company specified an air entrained 0.40 water-cement ratio concrete, galvanized-steel connections, a penetrating sealer for the exposed top parking level and carbon fiber mesh added to the 3.5-inch flanges on the double tees instead of welded-wire fabric.

The pre-topped double tees are 60 feet long, with "lite" walls (shear walls with punched openings) spaced along the north-south length, which are 12 inches thick and 30 feet long, and along the east-west width 8 inches thick and 14 feet long. The structure rests on a 4-foot-thick reinforced-concrete mat foundation, which was used rather than driving piles, Rowland notes. The mat actually is shaped like a donut, with the center 20 feet of the structure not supported by the mat to eliminate some of the mass.

"It's unusual to use this approach, but the administration was concerned about potential impact to the historic stadium if piles were driven," Rowland says. "The benefit is that we don't have to worry about any settling." The mat foundation also provided a significant space in which to stage components, ensuring no other portions of the campus were disrupted during erection.

Two cranes were used to erect the components, which were completely set in place in about three months. The process was complicated by building the structure into a hill, due to a sloping site that has the first level of spaces underground at one end. "The erection process was flawless," Tochiki says.

The project features a variety of horticultural elements, including several planting beds, a rain garden, and a living green wall, which were designed in conjunction with the school's horticulture department, which will maintain them. The areas will serve as a hands-on learning tools for students while providing the neighborhood with greenery and an ever-changing amenity.

Turkey's SU-NAC – Precast Lattice Defines Structure

The use of precast concrete to make a statement for university facilities extends around the world, as can be seen in its use in the design of Sabanc University's Nanotechnology Research & Application Center (SU-NAC). The facility, in the high-seismic industrial Marmara region of the Western Anatolia part of the Turkish Republic, was constructed under the direction of the Turkish Council for Science & Technology and architecturally designed by Cannon Design.

The two-story structure features laboratories and classrooms fronted by an atrium space enclosed by a precast concrete structural façade. The façade was designed to represent the lattice structure of a nanotube, explains Dr. Özgür Bezgin, chief of research and development at Yapi Merkezi Prefabrication Inc., the local precaster that structurally designed, produced, and installed the precast concrete components. The 449-foot-long precast concrete structural lattice is positioned within a hypothetical oval plan surrounding the rectangular footprint of the building. The lattice consists of 53 modules, each 24 feet high and 20 inches thick, cast with high-strength, white concrete.

SU-NAC's structural façade was aligned along arcs that were defined by five radii, Bezgin explains. The lattice components both include thermal layers and house thermally insulated

Photos courtesy of Ozgur Bezgin

PROJECT SPOTLIGHT

Sabanci University Nanotechnology Research & Application Center (SU-NAC)

Location: *Marmara region, Turkish Republic*

Project Type: *Science center*

Designer: *Cannon Design, Boston, Mass.*

Owner: *Sabanci University, Istanbul, Turkiye*

Contractor: *Koray Insaat, Ankara, Turkiye*

Precaster: *Yapi Merkezi Prefabrication Inc., Istanbul, Turkiye*

Precast Components: *Lattice modules, each 24 feet high and 20 inches thick, cast with high-strength C60 grade white concrete.*

layered windows at mid-depth and function as a tilted light funnel to maximize daylight in the atrium.

"The precast lattice also forms an important part of the vertical face of the structure, so it had to simultaneously have its architectural, functional, and structural requirements considered," Bezgin says. Included in the architectural requirements was the need for the concrete mix to maximize reflectivity. White cement was chosen due to its lack of iron oxides, which make it twice as reflective as gray cement, which contain varying amounts of iron oxides, he explains. This switch eliminated the need to apply a reflective coating after installation.

The structural façade had to be transparent enough to allow the infusion of daylight and at the same time had to be strong and ductile enough to support the lateral and vertical loads of the heavy roof material, which consisted of cast-in-place concrete over corrugated metal decks supported by steel beams. "The façade had to be formed using the least amount of structural material to provide the highest amount of window area," Bezgin states. "But it also had to provide enough support for a heavy roof element and provide insulation for the atrium."

Only three types of precast concrete modules were designed to meet



The new Nanotechnology Research & Application Center at Sabanc University in Turkey features an innovative use of precast concrete as a structural lattice that symbolizes the work accomplished at the facility. The precast concrete lattice consists of 53 modules, each 24 feet high and 20 inches thick, with a layer of insulation sandwiched between two layers of concrete.

all of the needs of the various configurations of lattice. They comprise a 10-foot-wide piece (30 in all), a 5-foot-wide piece (20 in all) and a triangular piece with a maximum width of 15 feet (3 in all). These latter three pieces served as the bounding elements positioned at the ends of the façade.

The production sequence involved casting a layer of reinforced concrete, followed by the placement of a layer of XPS insulation precision-cut to match the concrete layer, then casting the second reinforced concrete layer. Prior to the placement of the second layer of concrete, deformed reinforcing bars were inserted through the insulation layer to provide shear connection between the two reinforced concrete layers. Composite fiber-reinforced plastic forms were used due to their versatility in forming curved shapes and ease of maintenance for the repeated production needs, which took three months.

Rods Connect Modules

The 10-foot triangular pieces each weighed about 7 metric tons apiece, while the 5-foot pieces weighed 3.5 metric tons, making them cumbersome to handle. Each prefabricated unit had four specially designed anchor points placed to ease handling. The modules were designed to withstand the imposed design loads individually, but they also were connected to each other through belt beams at the top and through rotation-permitting rods at the contacting elbows of neighboring elements.

"During construction, care was taken to provide as much mutual contact between neighboring units as possible to limit displacement," Bezgin notes. The prefabricated structural façade elements were lifted and placed into sockets cast into each module and grouted into place.

The radial beams that support the roof plate are supported by the façade at every 10 feet along the façade length, he adds. The roof plate that spans between the main structure and the façade over the atrium area has a variable span, creating different loads at differing points on the façade. Rather than producing each of the modules for a different load condition, the elements were grouped into four loading values along the roof slab.

The result is a dramatic sloped surface for the façade that create a lattice to infuse daylight during the day while allowing the spread of internal atrium lighting at night, increasing its visibility and eliminating the need for external façade lighting. The lattice design emphasizes its scientific statement both visually and through its use of a dramatic engineering concept.

"The prefabricated structural façade design and construction was an important challenge to be met," says Bezgin. "The project gave YMP the chance to provide a construction solution that met the architectural, functional, and structural requirements of the façade in a single step of construction. It also advanced structural-design and construction techniques. Initial architectural design called for separate vertical support elements for the roof, but this design managed to fit all the necessary structural requirements into the precast concrete lattice, creating a dramatic and imposing atrium space for SU-NAC."

These projects show some of the range of buildings in which precast concrete components are being used to help meet the needs of universities, community colleges, and even institutions overseas. They also highlight some of the innovative technologies and designs that can be used in today's structures to meet sustainable and project goals. The uses of precast concrete are diverse, but they all help achieve the same goals of creating innovative, functional, aesthetically pleasing, and cost effective structures for higher education. ■

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

Adapting Through Diversity

During a 55-year career, John Kosar has helped Burt Hill grow by creating a diversified portfolio that adapts to challenges in each market

— Craig A. Shutt

John Kosar, AIA, NCARB

Chairman Emeritus John Kosar saw his architectural firm, Burt Hill Inc. in Butler, Pa., grow from a six-person staff in 1962 to more than 1,200 employees at its height a few years ago. During that time, he helped the company diversify into a wide range of building categories as well as domestic and international markets. He's also seen many changes in preferred architectural styles, client needs, and material choices.

Having retired last fall, Kosar continues to consult with the firm, which in late 2010 was acquired by Stantec, a North American architectural/engineering/consulting giant. That company's growth and acquisition strategy—it acquired eight other construction-related firms that year—fits well with Burt Hill's expansionist philosophy.

"We have always tried to be very entrepreneurial in our approach," says Kosar. "Our goal was to grow by bringing in new blood, both experienced and new. Having that entrepreneurial spirit and recognizing how market conditions operate, our strategy was to be widespread in various market sectors." Those sectors include commercial/office/retail, housing (condos, dormitories, and hotels), education (higher-education and K-12 schools), healthcare, laboratories, and high-tech buildings. "That diversity helped us keep a nice, even keel and kept us growing."

History of Adapting

Kosar's own adaptability began early in his career—on his first day in the office, in fact. He began working with the firm's predecessor, Howard & Murphy, in 1957 when he was hired by Whitney Murphy as a co-op student while studying at the University of Cincinnati. At his first day on the job, he found Murphy packing boxes and was informed his boss was joining Perkins & Will. He began working full-time with Howard after earning his architecture degree in 1962.

Associates Ralph Burt and Alva Hill soon were named partners, creating Howard, Burt & Hill. After Howard retired, Kosar and Dick Rittelmann became partners in 1969, creating Burt Hill Kosar Rittelman Associates, which it remained until a rebranding in 2005.

"The main attraction, for both our clients and our employees, has been our reputation for cutting-edge design

One of the first projects Kosar designed using precast concrete components was the YMCA in Butler, Pa. Completed in 1967, it features double tees spanning the natatorium as well as precast concrete components for the awnings over the entryway. Photos courtesy of Burt Hill, Inc.

and the variety of market sectors we work with," Kosar explains. "As our reputation grew, we became a place to experience and encourage creativity and provide exceptional service to our clients."

Kosar has seen many changes over the years, even to preferred architectural styles. "We try to meet the owner's goals and preferences in every design, with no pre-set ideas," he explains. The firm relies on a set of 10 metrics that are weighed for each project. These factors included aesthetics, humanism ("how we can make the building work better for individual users"), performance, sustainability, and the building's story.

"We put those together and see what challenges arise, and then we work to overcome them. Everything has to happen within the project's context of surrounding buildings and environment, functional performance, and the statement the owner wants to make."

Owners' involvement also has evolved, he notes. "Clients today are much more knowledgeable about the functional needs of their projects and how they want them to work," he says. "They also are better informed about materials. They travel a lot and remain curious, so they can suggest ideas that help us stay up to date."

The new 16-story academic building at the Harrisburg University of Science & Technology features architectural precast concrete panels on its exterior and a total-precast concrete parking structure. The building features a 125-seat auditorium and outdoor roof gardens. The campus is entirely new and consists of four sectors: this academic center as well as a business incubator, student village, and corporate-office complex.

Material Evolutions

One of the materials that has evolved is precast concrete, Kosar believes. He has understood its capabilities since his first precast project in 1967, when he used double tees to span the natatorium and provide an entrance covering at the new YMCA in Butler, Pennsylvania. "I had become aware of precast concrete while I was an apprentice, and I knew it would be a great asset for moisture control in those areas," he says. "We installed indirect lighting on the tee's stems and created a very functional and aesthetic look."

Kosar specified the material for a number of projects over the years, including a call center for a national bank based in Pittsburgh in 2006, where security, durability, and long-term maintenance were key concerns. In the mid 1980s, it also was used to clad the headquarters for Beecham (now GlaxoSmithKline) in Pittsburgh, and the 27-story Liberty Center complex. "The style of buildings that owners were seeking in that period, with a strong, institutional feel, often made precast concrete a good choice."

Another notable project to use architectural precast concrete panels was a six-building office park in Pittsburgh. "It created a specific statement for the entire complex," he explains. "Brick was very dominant in Pittsburgh, so precast concrete created a new look and provided the forward-thinking statement that the owners sought."

Burt Hill continues to use precast concrete on current projects such as the Harrisburg University of Science & Technology, the Wheeling Hospital's new seven-story medical tower, and the SUNY Binghamton East Campus Housing, which featured architectural precast concrete panels with embedded thin brick.

"We're using precast concrete more today than ever," he says. "It's gotten to be a more adaptable material, and owners are better aware of its capabilities. We're also getting more assistance from precasters in meeting specific challenges and finding efficient ways to make full use of it."

International Markets Expanding

The company has diversified further through a strong presence in Dubai in the United Arab Emirates, where it operates an office with 600 employees, about the size of the domestic staff spread through nine U.S. offices. Their work began when a partner established contacts in the late 1990s and they gained several key projects. After the 9-11 disruptions died down, Burt Hill committed to the market and opened an office in 2004.

"Our clients like that we work there

The new 21-story medical office building at Thomas Jefferson University, the largest freestanding academic medical center in Philadelphia, was designed to minimize disruption to occupants while allowing for phased expansion in the future. The project features architectural precast concrete panels on its façade, blending several colors and decorative styles to create visual interest and emphasize both horizontal and vertical features.

'precast concrete created a new look and provided the forward-thinking statement that the owners sought.'

rather than bring the design back to America to complete. Once we were established, the office grew rapidly." The market has slowed with the world-wide recession, he notes, as it has in America. "Healthcare is still fairly strong, because they are looking to raise the bar for medical services."

That's also true in America, he notes, with the healthcare market "still hanging in there." He expects the next strong market will be manufacturing/warehouse/office structures due to pent-up demand. "Once the economy stabilizes, we expect it will take off."

The firm also sees great potential for its office in India, which it opened in 2007. "That's a very active market," he notes. "They haven't slowed down much, and the way they are growing, they will be a substantial market over the next five years."

Kosar will be involved in marketing the firm through his consulting services, which he will continue at least through the end of the year. The rest of his time will be spent "traveling and enjoying life" after 55 years of not really working, he says.

"I never had to work in my life, because I totally enjoyed what I did," he says. "I made a lot of friends among owners, colleagues, contractors, suppliers, and developers. I had a great cross-section of people to work with, and I'm glad to have had the opportunity to work with them. It was very enjoyable, and very satisfying." ■

The East Campus Housing facility at SUNY in Binghamton, N.Y., consists of four residential halls making up the new Dickinson Community. The dorms will be clad with architectural precast concrete panels embedded with thin brick to blend with other campus structures. The work is expected to be completed by the fall of 2013.

The Aesthetic Versatility of Precast

Aesthetics is of great importance to universities. Many universities' structures relate to the very culture and tradition that the university was founded on. In other words, they are not just structures or buildings, but rather expressions of what the university stands for. Sometimes, aesthetics are used to create a focal point for the university, marrying tradition with innovation. Whether a project needs a traditional look, or needs to make a cutting edge statement, precast concrete provides high performance aesthetic versatility to accomplish your goals.

Precast concrete is available in practically any color, form, and texture. Precast concrete can also be veneered with other traditional building materials such as brick, granite, limestone, terra cotta, tile, and more. This provides the look and feel of these materials while adding all the benefits of precast concrete.

Different finishes can also be combined for one project, even in one panel, without requiring multiple trades and additional detailing for movement and waterproofing. It offers an efficient way to develop a multitude of façade treatments while reducing costs and risk.

The next few pages show some of the capabilities of precast concrete's aesthetic versatility on higher education projects throughout the United States.

Montclair State University Parking Structure

Montclair, N.J.

Architect: *Clarke Caton Hintz, Trenton, N.J.*

Structural Engineer: *Fay Spofford Thorndike, Fairfield , N.J.*

Contractor: *Epic Management Inc. Piscataway, N.J.*

Owner: *Montclair State University, Montclair, N.J.*

Precaster: *Nitterhouse Concrete Products, Chambersburg, Pa.*

Photo: Nitterhouse Concrete Products.

To help the state's second-largest university reach its governing board's goal of increasing its student body to 18,000, a new seven-and-one-half level, 1,532-space parking structure was built. A bright-white, lightly sandblasted concrete mix was used for the exterior panels and walls, which contrasted sharply with the vibrant red accents used on the panels, the roof, and the stair towers. The design of the exterior precast concrete also featured open arches and reveals to replicate the Spanish mission-style architecture of the other campus structures.

A key innovation on the project was the use of the bolted-on precast concrete arches. The architect designed the arches in pieces that could be shipped easily to the site, then bolted and welded to the spandrels. As a result, a fully rounded arch spandrel was achieved at a fraction of the cost of having to produce and erect the arched spandrels as one composite unit.

The design also incorporates a walkway occurring at the southern corner of the structure that connects the facility with the existing campus pedestrian circulation system.

University of Scranton, Condron Hall

Scranton, Pa.

Architect: *Burkavage Design Associates, Clarks Summit, Pa.*

Precast Architect: *Equus Design, Belmont, Mass.*

Structural Engineer: *E.D. Pons & Associates, Wilkes-Barre, Pa.*

Contractor: *Quandel Enterprises, Harrisburg, Pa.*

Owner: *University of Scranton, Scranton, Pa.*

Precaster: *Oldcastle Precast Building Systems, Edgewood, Md.*

Photo: courtesy of Oldcastle Precast Building Systems.

Condron Hall, at the University of Scranton, was designed and completed in just ten months. The 108,000 sq. ft., seven-story, student residence hall provides 386 beds in a two-bedroom suite-style arrangement. The structure replaces older, less desirable facilities and improves the quality and consistency of undergraduate housing on campus.

To blend in with the rest of the campus, thin brick of different colors and coursing patterns was embedded into precast concrete wall panels. Several brick colors and sizes were specified in the panels–using more than 125,000 thin brick units. The precast wall panels also included lightly sandblasted window trim, banding, and corner pieces to replicate limestone. Also, the University seal and building name were cast into the precast panels at the entrance using a form liner.

The project utilized a total precast concrete building system. The interior and exterior walls, floors, columns, beams, stairs, and the roof were all made of precast concrete. This allowed unobstructed clear spans and permitted the project to meet the tight timeline.

Photo: ©Vince Streano/Walker Parking.

Duke University Research Drive Parking Structure

Durham, N.C.

Architect: *Ratio Architects, Indianapolis, Ind.*

Structural Engineer: *Walker Parking Consultants, Indianapolis, Ind.*

Contractor: *Bovis Lend Lease Inc, Durham, N.C.*

Owner: *Duke University, Durham, N.C.*

Precaster: *Gate Precast, Oxford, N.C.*

Precast Specialty Engineer: *ETE Inc. Matthews, N.C.*

The new parking garage is the first, free-standing, single-use parking structure certified by the US Green Building Council in the U.S., earning 31 LEED® points. It is also the 19th LEED certified project at Duke University. It is located in the research zone of the campus adjacent to a medical clinic. Several new building projects in the area eliminated surface parking and necessitated the construction of a new facility to provide parking to students, faculty, visitors, and patients. Garage visitors are educated about sustainable design through learning centers in the elevator lobbies.

The architectural context of this garage blends well with the surrounding buildings but also provides for a sustainable green design. The precast concrete spandrels and column covers provide a monolithic color at a distance while the medium-sandblast finish allows the red stone aggregate to provide a mix of color close up. The mixture of precast concrete spandrels and the terra cotta and stone material at the lower levels provide a unique design solution, which gives the facade a variety of textures and colors to reduce the scale of the building. The precast column covers provide a vertical element to the facades while concealing the concrete columns. Reveals in the precast provide a more human scale and align with the curtainwall mullions and tile joints. The structure also incorporates green walls and roof canopies.

University of Wisconsin Madison, Physical Plant

Madison, Wis.

Architect: *Strang Inc., Madison, Wis.*

Structural Engineer: *Arnold & O'Sheridan, Madison, Wis.*

Contractor: *Kraemer Brothers, Plain, Wis.*

Owner: *University of Wisconsin Madison, Madison, Wis.*

Precaster: *Mid-States Concrete Industries, South Beloit, Ill.*

Photo: courtesy of Mid-States Concrete Ind.

The UW Physical Plant was a project of necessity. The relocation of the Physical Plant was needed to accommodate growth and decompression from the other physical plant facilities and to make room for a nearby heating plant project.

Continuing with UW's commitment to architecture, the precast concrete wall panels were finished with two colors of thin brick on the three main elevations of the structure, which complemented the campus neighborhood. The brick was fairly detailed using soldier coursing, reveals, and returns to match existing architecture. The rear elevation was a buff-colored, lightly sand-blasted finish. All the wall panels were insulated. "We saved valuable weeks using precast instead of conventional masonry," said Bill Kolar, project manager for Kraemer Brothers. The precast allowed the building to be erected in just 13 days.

Central Community College Residence Hall

Columbus, Neb.

Architect: *Wilkins Hinrichs Stober Architects, Kearney, Neb.*

Structural Engineer: *Performance Engineering, Omaha, Neb.*

Contractor: *BD Construction, Columbus, Neb.*

Owner: *Central Community College, Grand Island, Neb.*

Precaster: *Coreslab Structures (OMAHA), LaPlatte, Neb.*

This project is part of a larger housing master plan for Central Community College's Columbus Campus. The new residence hall is phase one of the multi-phase project; thus, it had to set the standard for aesthetics and constructability. The building consists of 18 rooms which can house up to three students each. There is a common living area, as well as kitchen, study, and laundry space.

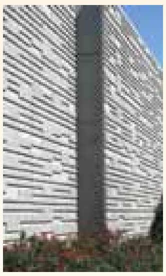
Photos: Paul Brokering Photography.

The use of precast concrete insulated wall panels served structural, thermal, and electrical purposes all while meeting the owner's exterior and interior aesthetic needs. The attractive exterior aesthetics were achieved by using a combination of acid etching, sandblasting, and thin brick. The unique size of the panels provided opportunities for the designers to create interest and to control cost by using repetitive patterns enhancing the look of the façade. These large 16 ft. x 16 ft. panels also made it possible to hide panel joints with the interior partition walls, providing a durable and seamless interior finish ideal for residence halls. The precast concrete manufacturer focused on providing a smooth back finish and strategically located lifting devices to provide a high quality finish surface ready for paint.

Missouri State University, JQH Arena

Springfield, Mo.

Architect: *Ellerbe Becket Inc., Kansas City, Mo.*
Structural Engineer: *Martin / Martin, Lakewood, Colo.*
Contractor: *JE Dunn Construction, Kansas City, Mo.*
Owner: *Missouri State University, Springfield, Mo.*
Precaster: *Prestressed Casting Co., Springfield, Mo.*



Photos: Prestressed Casting Co.

The 11,055 seat arena is home to the Missouri State Bears and Lady Bears basketball games and also used for concerts and other large capacity events. Precast concrete was selected for the exterior of the arena for economic reasons. A key challenge was to create a precast panel that did not look plain on the tall walls. The solution was a textured liner, using an "Oak Tree Bark" finish, with an intricately laid out pattern to match each adjacent panel. The result was a unique façade that complements the surrounding architecture and pays tribute to the region. The precast concrete wall panels were also left exposed to the interior providing a durable surface with a Frenzo trowel finish.

Using precast concrete as the structural system also allowed many advantages. For example, the column and raker beam system allowed for an open, usable space under the spectator seating. The project was also able to be erected in just 75 days, which was ahead of schedule, despite being constructed during the wettest spring on record and uncovering an artesian well during excavation.

University of Nebraska - Maverick Village Parking Structure

Omaha, Neb.

Photo: Kessler Photography, 2009.

Architect: *Holland Basham Architects, Omaha, Neb.*
Structural Engineer: *Nielsen-Baumert Engineering Inc., Omaha, Neb.*
Contractor: *Kiewit Building Group Inc. Omaha, Neb.*
Owner: *University of Nebraska at Omaha, Omaha, Neb.*
Precaster: *Coreslab Structures (OMAHA), LaPlatte, Neb.*

This unique 280,485 square foot, five-level parking structure, comprised completely of precast concrete, adds nearly 900 spaces for the university.

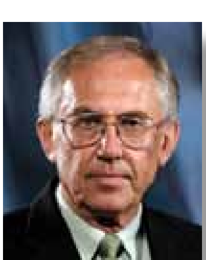
One of the key objectives for this project was not only to conform to the campus standards, but to design the exterior facade to look like a classroom building. Great detail was integrated into the exterior wall panels, including thin brick, exposed aggregate, sandblasting, and multiple reveal patterns, to help achieve this objective. Although intricate in detail, the architect's design allowed for only two mirror image casting forms for the vast majority of the exterior panels, saving both cost and time. Additionally, the wall panels function as load bearing shear walls. The design strategy of using one component to serve multiple functions helped to maximize the time and material cost savings of using precast concrete. Because of the length and stiffness of the garage, the stair towers in opposite corners were designed as free standing to alleviate thermal stress accumulation.

The Current State of Fire Design

— By Roger Becker, P.E., S.E.

Many decisions in building design hinge on the code requirements for fire-resistive construction. While the fire-resistance ratings required by the codes may be modified with new code editions, the technology of fire resistance has changed very little in the past 50 years. Early in the development of the precast/prestressed concrete industry, fire resistance was considered an important attribute of precast concrete construction, so significant resources were dedicated to fire research. The results of that research are still the basis for much of what is known about the fire performance of structural concrete elements today.

What has changed over the years is an increased reliance on detection and suppression of fires, with a corresponding decrease in attention to fire containment within the building. The International Building Code[1] (IBC) now allows substantial building areas and heights to be constructed (up to 70 ft. high and over 250,000 square feet of building area for B occupancies) entirely out of Type V construction where an approved automatic sprinkler system is provided. Type V construction consists of wood or light-gage steel framing with as little as one hour of protection for many building elements. This shift in emphasis toward an increased reliance on fire protection systems as the primary life-safety component in fire-protective design ignores the issue of functional resiliency and facility durability.



– Roger Becker, P.E., S.E., is managing director of research and development for the Precast/Prestressed Concrete Institute in Chicago, Ill.

Functional resilience is the ability of a building to resist damage and return to usefulness from the effects of natural and man-made disasters. For architects increasingly focused on the demands of owners for designing high performing buildings, functional resilience may well become a key guiding principle in designing buildings that not only meet the code, but limit fire and sprinkler damage, facility downtime, and the costs and carbon impact of restoring the building to full operation following a disaster.

Insurers are increasingly becoming involved in the fire-resistive construction of major facilities. For specific occupancies, such as retail, office, and other facilities, the owner may require the architect to comply with Factory Mutual (FM) design requirements, and obtain review and approval of FM for insurance purposes. FM conducts its own testing of building products and fire assemblies and their requirements may exceed the minimum building code requirements.

Designing for Fire

Accounting for fire requirements involves two tasks. The first task is to establish the required rating for various building elements. This is accomplished by defining the use and occupancy category for the building, selecting the construction type based on the height and area of the building, and then identifying the required fire resistance rating for the various building components based on the construction type. The process is clearly more complex than this as special features of a building are considered.

The second task is to select construction materials that will provide the fire resistance determined from the code review. Most jurisdictions today have adopted some edition of the IBC perhaps with local modifications. As codes have evolved, the required fire-resistance ratings have been tweaked. However, from the 2000 IBC through the 2012 IBC, other than section number changes, the means by which fire resistance is provided by various construction materials has not changed.

Providing Fire Resistive Construction

The American Society for Testing and Materials (ASTM) standard E119, Standard Test Methods for Fire Tests of Building Construction and Materials[2], is the primary document that has been used to establish fire resistance in the United States and dates back to first adoption in 1918. A fundamental component of the standard is the time-temperature curve. For any fire test, this curve defines the temperatures that must be achieved and the rate of temperature gain. The curve is reproduced in **Figure 1.** This standard also defines the acceptability criteria to establish the endpoint for a fire test. Those criteria include:

- Structural endpoint, which is defined by collapse of the element.
- Heat transmission endpoint, which is defined by the average or peak temperature on the opposite side from the fire.
- Flame endpoint, which is defined by the passage of flames or gases hot enough to ignite cotton waste on the opposite side from the fire.
- A hose stream test, which the walls must withstand.

The standard further defines how various construction elements are to be tested. For example, floor and roof specimens shall not be less than 180 square feet in area and neither plan dimension shall be less than 12 feet. Since most test furnaces do not exceed the minimum specified dimensions by very much, it is clear that fire tests are not representative of practical construction. However, the same rules are applied to all materials, so there is a basis for comparison.

One of the important concepts contained in the ASTM E119 standard is the differentiation between restrained and unrestrained fire ratings that are applied to floors and roofs. As a structural element is heated in a fire, the material naturally needs to expand. If the surrounding construction is stiff enough and strong enough to restrain this expansion, the assembly is considered restrained. If the element can freely expand as it is heated in a fire because there is no surrounding structure or because the surrounding structure is not adequate to restrain the expansion, the assembly is considered unrestrained. The issue of restraint is an important consideration as decisions are made in developing a building concept and some examples are provided in Appendix X3 of the ASTM E119 standard.

The endpoints noted for the ASTM E119 acceptance criteria are logical whether or not a test is conducted. During a fire, the material strengths will be reduced at elevated temperatures. If the material strength diminishes to the point where the element strength is less than the load demand, collapse will occur. The primary mechanism for improving resistance for the structural endpoint for concrete elements is to increase the amount of concrete cover over the reinforcement. Additional concrete will protect the steel reinforcement and reduce the temperature of the steel during a fire. The steel will then maintain a higher percentage of its room temperature strength. When the concrete cover is increased to improve fire resistance, the effective depth of the reinforcement is decreased. In this case, additional reinforcement will be required to resist normal loads at room temperature.

The objective of the heat transmission endpoint is to protect combustible contents on the opposite side of the element from the fire. This endpoint is a function of the type and mass of concrete available. For example, the required fire resistance rating may govern the thickness of a wall or floor slab based on the heat transmission endpoint. **Table 1**, which can be found in many references, summarizes minimum wall and slab thicknesses required for various fire resistance ratings. Note, for example, a 6 inch thick slab might be ideal for building dimensions and structural adequacy, but it would not be sufficient for a three hour fire rating based on heat transmission if it were constructed of siliceous aggregate concrete.

Underwriters Laboratories, Inc. (UL) has conducted countless fire tests on structural assemblies using ASTM E119 as the standard. Many construction assemblies received fire resistance ratings as a result of UL testing. UL assemblies have been popular with architects and code officials because they are easy to understand and readily acceptable. An assembly built in conformance to the rated assembly construction automatically gets the UL fire resistance rating. However, this also illustrates one of the difficulties with a UL fire rated assembly. For the fire resistance rating to be achieved, the actual construction must duplicate the tested assembly. Most assemblies are also product specific. The challenge becomes using more modern materials and techniques that do not substitute directly into the UL assemblies.

The International Building Code has simplified the whole issue of fire resistance for structural elements. While the IBC allows use of tested assemblies, such as those provided by UL, there is no requirement that a construction must be one of those assemblies. A UL designation is not required by code.

The IBC provides alternate methods for establishing fire resistance and the provisions are located in Chapter 7 of the IBC. Using the 2012 IBC as the reference, the first method provided is in Section 721 entitled Prescriptive Fire Resistance. The resource provided in that section is Table 721.1 where various structural elements are described and the re-

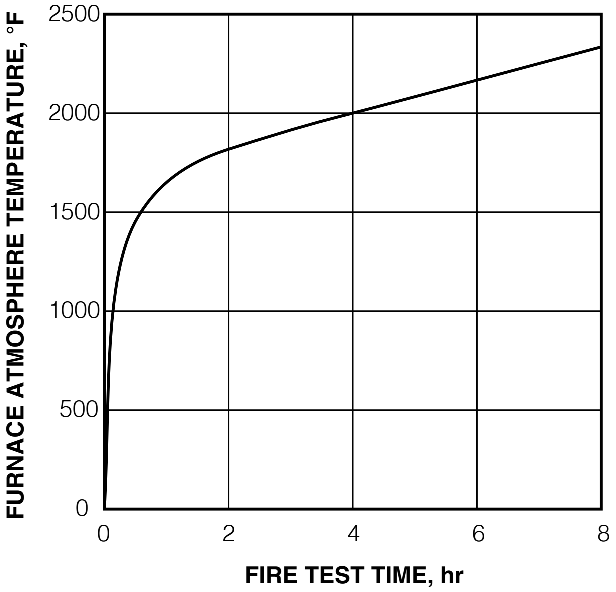


Figure 1. Time-temperature curve from ASTM E119.

Table 1. Minimum wall or slab thickness (in.) based on heat transmission.

Aggregate Type	Fire Resistance Rating, hr				
	1	$1^1/_2$	2	3	4
Siliceous	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

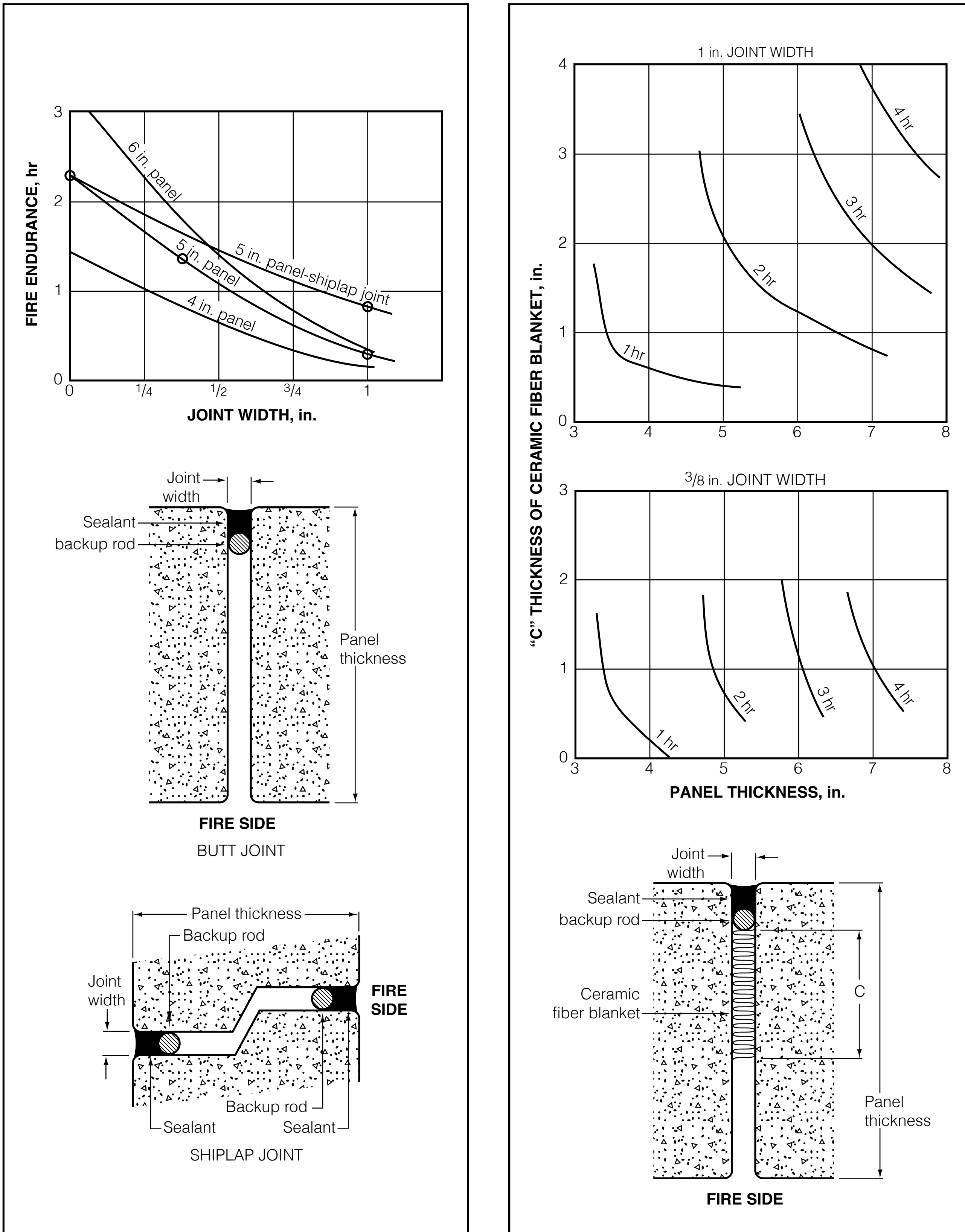


Figure 2. Fire resistance of precast concrete wall joints.

quired element attributes are specified. For example, for concrete slab construction, the minimum concrete cover over reinforcing steel and minimum slab thickness are specified. This is similar to the UL test assembly approach except that all materials are generic.

The second method is in Section 722 and is entitled Calculated Fire Resistance. Section 722.2 covers concrete assemblies. The term "calculated" is a bit misleading because very few calculations are required to use these provisions. Tables and graphs are provided for various concrete attributes where defining the system is as simple as pulling numbers from a chart. This section does provide information on concrete construction assemblies that are not covered in Section 721. For example, multicourse floors and combinations with finish materials are covered.

The IBC refers to two other standards available for calculated fire resistance. ACI 216.1/TMS 0216, Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies[3], essentially repeats the material from IBC Section 722 and provides some analytical methods for determining fire resistance. The IBC also refers to ASCE 29, Standard Calculation Methods for Structural Fire Protection[4], for fire resistance of steel assemblies. That document also includes a chapter on plain and reinforced concrete, which essentially duplicates the material from IBC Section 722. These two documents are applicable for determining fire resistance of precast concrete.

Precast concrete can satisfy everything that has been described to this point. Many precast concrete suppliers have UL numbers for various assemblies. Again, it should be emphasized that a UL designation is not required by code. Either the prescriptive or calculated methods of the IBC may be used with precast and precast/prestressed concrete walls, beams, columns, floors, and roofs.

However, precast concrete has taken fire resistance a step further. PCI publishes MNL 124, Design for Fire Resistance of Precast Prestressed Concrete[5] .It is based on years of fire testing of various components and assemblies of precast concrete. The data obtained from this testing provides for a truly engineered approach to fire resistance. Much of the data from the IBC is included in the manual, but it can also be used to evaluate systems that do not conform to those requirements.

For example, if an existing building were to be modified for a different occupancy requiring a higher fire-resistance rating, the structure could be evaluated by calculation using the data in the manual. Keeping in mind the endpoints defined by ASTM, data are provided to determine the internal steel temperature at the required fire endurance, a reduced steel strength could be calculated, and load capacity could be compared to the demand. For heat transmission, data are provided for the addition of various materials to enhance the insulation capacity of the existing concrete. These procedures have collectively become known as rational design.

For precast concrete walls that must be fire resistive, consideration must be given to the joints between the wall panels. **Figure 2** is taken from MNL 124 to illustrate how wall panel joints can be treated to provide fire resistance ratings to four hours. One last example is floor penetrations. Holes through fire rated floors for power, data, or communication must be protected. Based on fire tests[6], information is provided for detailing such penetrations.

The precast concrete industry has contributed significantly to the understanding of fire performance of concrete construction. Engineers such as Armand Gustaferro, Melvin Abrams, and Walter Prebis distilled fire-test data to develop engineering techniques that are transparent and straightforward in their application. We are grateful that their work allows construction of functional, resilient, and fire safe buildings in precast concrete.

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

Student Residences Open Door to Partnerships

Total precast concrete structure helps Montclair State dormitory finish ahead of schedule and on budget, providing prototype for public-private partnerships in New Jersey

— Craig A. Shutt

In 2009, the New Jersey legislature passed the Economic Stimulus Act that allowed public organizations to work with private groups to develop projects that benefited both parties. One of the first projects to take advantage of the law was the $132-million Heights residence hall at Montclair University in Montclair, N.J. The two-building, 565,000-square-foot project used a total-precast concrete structural solution to overcome extraordinary site conditions and pursue LEED Silver certification while coming in ahead of schedule and on budget.

The complex consists of four residence towers rising six to eight stories. The large facility provides 1,009 dormitory suites with individual bathrooms and vanities, as well as amenities such as common areas, laundry rooms, multi-purpose rooms, and study rooms. Each building has a two-story common area, with one of the buildings housing a 25,000-square-foot cafeteria with five menu stations.

The project took advantage of the new public-private partnership law, which provided the framework for

All photos in this article are courtesy of Liam Frederick

This aerial view shows how the new residence halls at Montclair State University were offset to better align with the topography, reduce the scale of the project and provide a variety of scenic views from the rooms. The foreground halls are located behind the red-roofed recreation center and are connected by the new cafeteria space.

Capstone Development Partners to collaborate with the university on its first such project. Under the agreement, the university provided the land while Capstone's development team financed, designed, built, and manages the project. After 30 years, ownership shifts to the university.

Capstone advised the university while the legislature was considering the bill and then was contacted by administrators when it released its RFP on the project, explains Bruce McKee, Capstone principal. Interestingly, the university suggested five alternative sites for the housing complex, but Capstone proposed another.

'It was a difficult site and an aggressive schedule, with a lot of program challenges.'

The dormitory project took advantage of the new public-private partnership law, under which the university provided the land while the development team financed, designed, built, and manages the project. After 30 years, ownership shifts to the university.

PROJECT SPOTLIGHT

Montclair University Residence Hall

Location: *Montclair, N.J.*

Project Type: *University dormitories*

Size: *565,000 square feet*

Cost: *$132 million*

Architect of Record: *Paulus, Sokolowski & Sartor, Architecture & Engineering, Warren, N.J.*

Design Architect: *Design Collective Inc., Baltimore, Md.*

Owner: *Capstone Development, Birmingham, Ala.*

Structural Engineer: *PS&S, Warren, N.J.*

Design-Build Contractor: *Terminal Construction Corp., Wood Ridge, N.J.*

PCI-Certified Precaster: *High Concrete Group LLC, Springboro, Ohio and Denver, Pa.*

Precast Components: *Precast concrete load-bearing insulated sandwich wall panels, hollow-core plank*

Difficult, Rocky Site

"We visited the sites with our design and construction team and ultimately proposed modifying and expanding one of the sites," he explains. The suggested site was over a former large quarry with uneven, rocky topography. "Our plan was to create a number of smaller structures that could respond to the extreme topography in an organic way and produce a repetitive design that still tied very closely to the institution's architectural style. It helped with constructability while adding site-planning interest and helped create the 'village' feel we were looking to create."

Terminal Construction Corp. of Wood Ridge, N.J., was selected to head the design-build team. The team used an eight-month preconstruction planning process to plot out design, material choices, and procedures before the project began. That time paid off, as the original tight 15-month construction schedule was able to be condensed to 13 months, ensuring completion well ahead of the school's opening for the 2011 fall semester.

"It was a difficult site and an aggressive schedule, with a lot of program challenges," says Bruce Corke, project manager at Paulus, Sokolowski & Sartor, Architecture & Engineering in Warren, N.J., which served as architect of record. "It was designed and built very quickly, with a lot of the configuration and layout dictated by what the site would allow us to do." Design Collective Inc. in Baltimore served as design architect.

Total Precast Solution

The total-precast concrete structural solution consisted of load-bearing precast concrete wall panels and hollow-core floor planks. The wall panels feature two wythes of concrete, a three-inch outer layer and a five-inch inner layer, sandwiching three inches of rigid-foam insulation. The layers are secured with proprietary carbon-fiber shear trusses to minimize thermal transfer while transferring shear forces between the layers.

This approach makes the panels fully structurally composite, with both the inside and outside layers handling wind and seismic loads. The thicker inner layer supports gravity loads and provides a smooth, durable finished interior surface that withstands abuse. The concrete's two layers of thermal mass and interior insulation provided a uniform R value of 15.

"The project's timeline needed the

The first level of the dormitory buildings feature a beige tint and reveals that add interest at the pedestrian level.

'Precast concrete provided the structural frame, the thermally insulated envelope, the architectural appearance and the fire rating all in one piece.'

innovation of precast concrete walls," states George Stankiewicz, project engineer for Terminal Construction. "Using the load-bearing insulated panels ensured the project's wall system was complete once it was assembled. And the insulating R-value of the skin contributed to the structure's energy efficiency in a single application."

Fabricating precast concrete components offsite also sped up construction, as considerable foundation work was needed, according to Glenn Kustera, structural engineer for PS&S. "At this old quarry site, the remaining rock levels varied in depth greatly over the site," he explains. During excavation, crews would suddenly be stopped by a 20-foot vertical wall of rock. As a result, to accommodate the varying rock heights, foundations ranged from walls supported by continuous stepped-strip footings to grade beams supported by piers and isolated spread footings. Precast concrete bearing walls were placed on the cast-in-place walls or grade beams.

"Coming out of the ground on this project was very interesting," Kustera says. "Each time a new rock height was uncovered, we had to modify the foundations on the fly. The goal was to take this curveball and create uniform footings, so the precaster could complete his shop drawings and cast panels based on the knowledge that certain footing conditions would be created, no matter how we reached that condition."

Construction maneuverability was complicated further by steep grades and existing buildings around the site, including a recreational center and parking structure, along with a steep cliff to the east. The buildings are located along campus circulation paths to the main academic buildings and the recreation center.

"The wing configuration of the structures came from the nature of the topography," Corke explains. "Precast concrete was decided on early in the process due to its capabilities to be cast off-site while foundation work was done, speeding construction, and also because it lends itself well to replicating housing units. The spans it can provide establish parameters that work well for hotels and dormitories."

Wings Offset

The wings were offset in order to reduce the massive structures' scale and to vary the perspective from the rooms. "We wanted to add creativity to the design by providing angles that created different views from rooms and add visual interest outside," Corke says. "The breakdown into separate wings worked very well with the surrounding roads and topography."

The buildings were organized around central common cores with wings or residential suites radiating from the cores. "This design provides efficient circulation as well as close supervision of residents," Stankiewicz explains. The common core offers basics of residential life, including mail services, lounges, TV and meeting rooms, study rooms, kitchenettes and vending machines, and laundry rooms. Offices have been provided in each building, as well as apartments for Capstone's staff, who reside on campus year round. The dorm suites are located in towers between six and eight stories tall, depending on site grades.

The towers were designed with shear walls on the short sides of the buildings, which bear the brunt of the wind loads, Kustera notes. The buildings sit on top of the first ridge of the Watchung Mountains, several hundred feet up. "The wind loads can be 80% higher at that location than in other, lower portions of the campus," he explains. "So those shear walls have to work pretty hard."

The precast panels and plank also provided all of the fire resistance required to meet the building code, Kustera adds. "Their inherent composition met the code automatically, eliminating that concern. Precast concrete provided the structural frame, the thermally insulated envelope, the architectural appearance and the fire rating all in one piece. It's a very efficient system."

Mission Style Created

The finishes of the precast concrete panels were designed to complement the Mission Style design featured throughout the campus. The bright-white concrete mix on upper floors contrasts with beige coloring and reveals used on the first level to replicate the look of stone blocks.

Windows featured frames that jut out several inches to create depth. Ledges at the first and top floors, along with higher towers at the entries, provide more visual interest. Red accents were created as a contrast, including the clay-tile roof on the cafeteria, aluminum tower caps and gutters, and red steel building railings and pergola.

Mock-ups of the different elements were created and reviewed by the designer and developer, Stankiewicz says. "Once accepted, the suite design allowed for repetitiveness in assembly, so the learning curve decreased rapidly. Punch list items were managed and kept to a minimum."

"Designing the building into wings helped make the Mission Style architecture more prominent," Corke says. "All of the elements, both horizontal and vertical details, help reduce the scale of this major project. And the wings provide scenic views of the mountains."

Erected Simultaneously

Once the foundations were set, High Concrete Group delivered more than 1,650 wall panels and 4,500 hollow-core floor planks. "The delivery of all the pieces was flawless," Stankiewicz says. Two lattice cranes assembled the pieces with continuous operation, each working on a dormitory complex. At some point, crews were shifted from one site to the other to keep progress moving.

"The goal was to ensure we had a weather-tight building in place before winter hit, and we achieved that," Stankiewicz says. With erection beginning in July 2010, the building was completely enclosed early in November, when interior trades began work that continued through the winter. The precast concrete erection took 100 days to complete. "Manufacturing the concrete components off site saved so much time," Corke agrees.

'Designing the building into wings helped make the Mission Style architecture more prominent.'

The repetitive nature of casting the components also helped the schedule, notes McKee. "There was a demanding schedule to achieve dry-in quickly so interior trades could get to work," he explains. "That goal fit well with precast concrete's strengths. Its repetition allowed pieces to be cast and delivered quickly. It helped with the schedule, the architectural character, and the quality that we wanted to achieve."

The erection, and in fact the entire construction process, moved smoothly, he adds. "The only real surprises we had were outside the project, in terms of some permitting snags and such," he says. "The rest went extremely well."

LEED Certification

At press time, the project had been submitted for LEED certification, with the anticipation of a Silver rating and the possibility of Gold. LEED certification was necessary to satisfy requirements of the private-public partnership guidelines. A range of efficient elements were included to achieve that goal.

The precast concrete components aided certification by providing high energy efficiency in the building shell, regionally manufacturing the materials, using recycled materials, and other factors. Site use also was enhanced by reclaiming a former parking lot for higher-density use. Nearly 90% of construction debris was diverted from landfills. Water efficiency, landscaping, and other site activities also were included.

An Energy Star-rated high-albedo EPDM roofing membrane was installed to cover nearly 75% of all roofing area, reducing the heat island effect and the amount of energy needed to cool the buildings. Wood-based materials were certified by the Forest Stewardship Council to ensure integrity for the forest ecosystem.

The mechanical system provides 750 tons of cooling through water-source heat pumps in each suite. Individual thermal-comfort controls provide ongoing accountability of building energy usage. The mechanical system uses enhanced LEED commissioning to ensure indoor air quality during construction, while upgraded refrigerant management provides zero use of CFC refrigerants.

To allow for the increased capacity to the campus infrastructure, a sanitary-pump station and nearly three miles of gravity sewer lines were woven through the residential streets of the city. "Roadways, parking lots, hardscape, landscaping, fire service, and stormwater management all contributed to permanently altering the campus and its lifestyle," says Stankiewicz,

The result is a dramatic addition to the campus that maximizes space and created a complex that fits organically into its surroundings. Administrators allowed students to select names for each of the wings through voting, increasing their ownership of the project and giving them additional pride in the place they call home while at college.

"The character of the site created a challenging project," says McKee. "But the solution also led to creating the architectural style that we wanted and provided a lot of the strong identity that the project ended up with." ■

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

The total-precast concrete structural solution consisted of load-bearing precast concrete wall panels and hollow-core floor planks. The wall panels feature 3 inches of rigid-foam insulation secured with proprietary carbon-fiber shear trusses to minimize thermal bridging while transferring shear forces between the layers.


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In addition to the inspiring stories of the rebuilding and memorial at the Pentagon and the Flight 93 National Memorial, six architects who offered their experience to help rebuild and memorialize Ground Zero will share emotions and anecdotes, including Daniel Libeskind, FAIA; David Childs, FAIA; Michael Arad, AIA; Craig Dykers, AIA; Steve Davis, FAIA; and Santiago Calatrava, FAIA.
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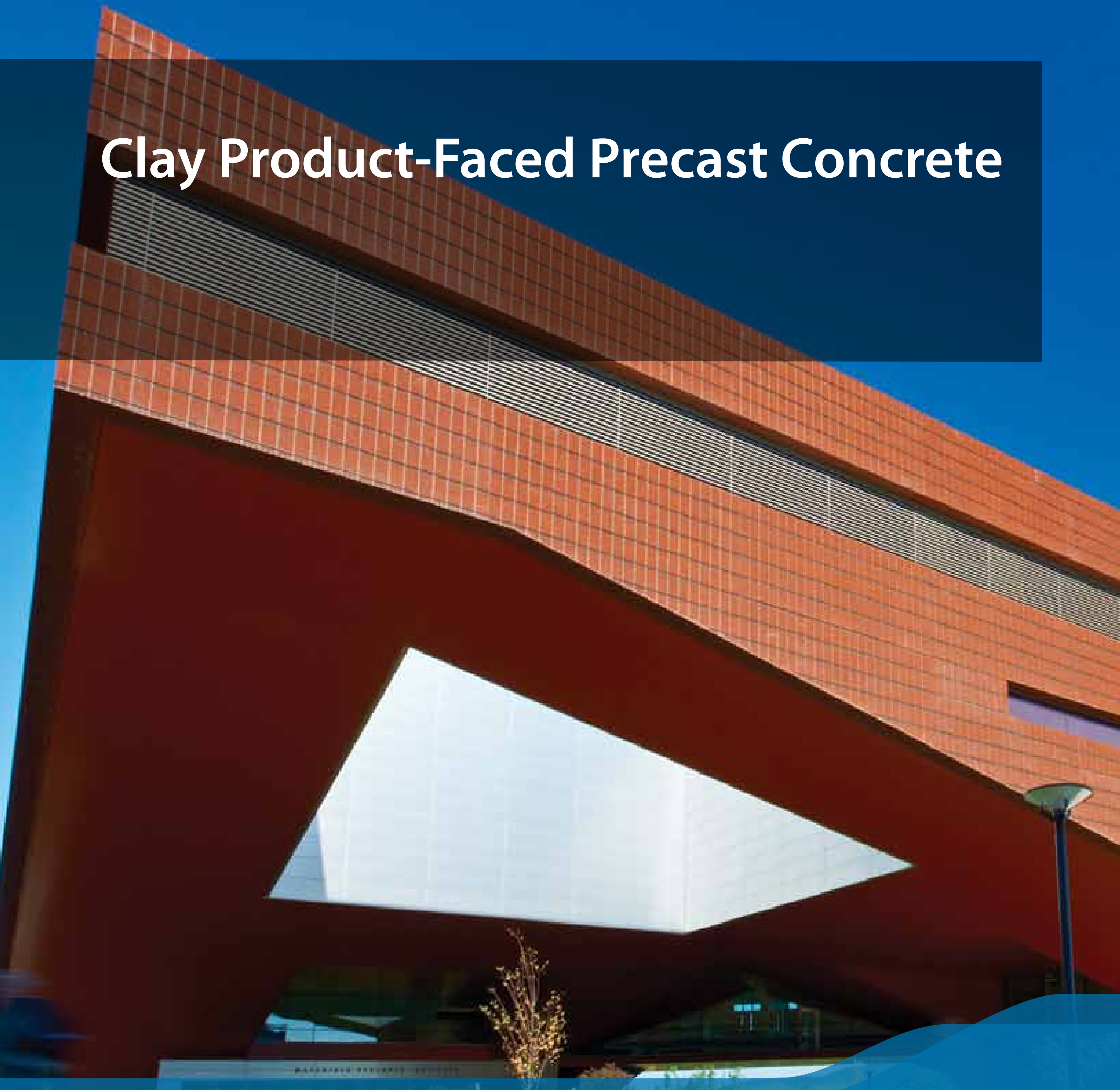
Clay Product-Faced Precast Concrete



PCI designer'snotebook

Clay Product-Faced Precast Concrete

The use of clay product-faced precast concrete has evolved since the early 1960s into the designer's choice for unlimited aesthetic options on all types of structures. It gives the architect the flexibility to combine the pleasing visual appearance of traditional clay products with the strength, versatility, and economy of precast concrete. Among the types of materials that can be embedded in the precast concrete are brick, ceramic tile, porcelain, and architectural terra cotta. These clay product facings may cover the exposed panel surface entirely or only part of the concrete face, creating accents. The demand for thin brick in precast concrete led PCI to develop a standard for embedded thin brick in precast concrete panels so that the design community can have control over the performance of their precast components.

Benefits and Advantages

The combination of precast concrete and clay products offers several important benefits and advantages over site-laid-up masonry. During the life cycle maintenance of these systems tuckpointing is eliminated, unlike traditional hand-laid units. Clay product-faced precast concrete units act as a rain barrier and not a rain screen.

Figure 1 Bonding patterns incorporated into the finished panel.

Precasting techniques allow complex and intricate details such as arches, radii, ornate corbels, and numerous bonding patterns to be incorporated into the finished panel (Fig. 1). This freedom of aesthetic expression could not be accommodated economically with site-laid-up masonry. Prefabrication ensures that building skills are transferred to the controlled conditions of the plant and away from the critical path of on-site activities.

Precasting allows a high level of dimensional precision and quality control. Concrete mixtures and batching, together with curing conditions, can be tightly controlled, whereas site-laid masonry may have variable curing and mortar qualities.

Plant production provides for year-round work under controlled environmental conditions, negating any on-site delays due to inclement weather or incurring the expense of on-site weather protection. It also allows the building enclosure, with floor topping and finishing trades, to continue without any weather delays. Clay product-faced precast concrete can eliminate the need for costly on-site scaffolding, material storage, equipment, and manpower and can greatly reduce the duration of masonry cladding time. Also, site disturbance, construction debris, and use of toxic cleaners are reduced. Clay product-faced precast concrete panels can eliminate many items necessary for traditional masonry such as dovetail anchors, flashing, and weep holes.

Panel configurations include a multitude of shapes and sizes: flat panels, C-shaped spandrels, soffits, arches, and U-shaped column covers. Repetitive use of any particular shape also lowers costs dramatically. Returns on spandrels or column covers may be produced by the sequential (two-stage) casting method or as a single cast, depending on the height of the return. Panels may serve as cladding or may be load-bearing, supporting floor and roof loads, and can even function as lateral load resisting elements (shearwalls).

General Considerations

Structural design, fabrication, handling, and erection considerations for clay product-faced precast concrete units are similar to those for other precast concrete wall panels, except that consideration must be given to the dimensional layout of the clay product material and its embedment in the concrete. The physical properties of the clay products must be compared with the properties of the concrete backup. These properties include the coefficient of thermal expansion, modulus of elasticity, and volume change due to moisture, along with strict adherence to tight dimensional tolerances.

For design purposes, clay product-faced precast concrete panels may be designed as concrete members that neglect the structural action of the face veneer. The thickness of the panel is reduced by the thickness of the veneer. However, if the panel is to be prestressed, the effect of composite behavior and the resulting prestress eccentricity should be considered in design. Reinforcement of the precast concrete backup should follow recommendations for precast concrete wall panels relative to design, cover, and placement.

The height and length of the panels should be multiples of nominal individual masonry unit heights and lengths for effective cost control in the precast concrete production process. The actual specified dimensions may be less than the required nominal dimensions by the thickness of one mortar joint. For economical production, the precaster should be able to use uniform and even coursing without cutting any units vertically or horizontally except as necessary for precast panel joints and bond patterns. The PCI Standard for thin brick in precast concrete panels should be specified to ensure size uniformity, long term durability, and material compatibility.

PCI Standard for Thin Brick

The objective of this standard is to outline material standards and specification criteria for brick manufacturers to meet when supplying materials to precast concrete manufacturers. The intent is to establish acceptable dimensional tolerances and consistent testing standards for brick embedded in precast concrete systems. The brick manufacturers must confirm through the provision of independent test results that their brick products comply with the PCI Standard. The PCI Standard should appear in all specifications as the approved industry standard. Brick manufacturers have agreed to promote the compliance of their brick with this new standard.

The following parameters have been established based on the successful use of embedded brick in precast concrete projects. The parameters set forth for use in this standard are attainable brick properties that have been derived with input from brick manufacturers, precasters, engineers, and architects, as well as consideration of existing test results.

A. Thin Brick Units: PCI Standard, not less than $^{1}/_{2}$ in. (13 mm) nor more than 1 in. (25 mm) thick with an overall tolerance of plus 0 in., minus $^{1}/_{16}$ in. (+0 mm, -1.6 mm) for any unit dimension 8 in. (200 mm) or less and an overall tolerance of plus 0 in., minus $^{3}/_{32}$ in. (+0 mm, -2.4 mm) for any unit dimension greater than 8 in. (200 mm) measured according to ASTM C 67.

1. Face Size: Modular, $2^{1}/_{4}$ in. (57 mm) high by $7^{5}/_{8}$ in. (190 mm) long.
2. Face Size: Norman, $2^{1}/_{4}$ in. (57 mm) high by $11^{5}/_{8}$ in. (290 mm) long.
3. Face Size: Closure Modular, $3^{5}/_{8}$ in. (90 mm) high by $7^{5}/_{8}$ in. (190 mm) long.
4. Face Size: Utility or Jumbo, $3^{5}/_{8}$ in. (90 mm) high by $11^{5}/_{8}$ in. (290 mm) long.
5. Face Size, Color, and Texture: **[Match Architect's approved samples] [Match existing adjacent brickwork]**.

    a. <**Insert information on existing brick if known.**>

6. Special Shapes: Include corners, edge corners, and end edge corners.
7. Cold Water Absorption at 24 hours: Maximum 6% when tested per ASTM C 67.
8. Efflorescence: Provide brick that has been tested according to ASTM C 67 and rated "not effloresced."
9. Out of Square: Plus or minus $^{1}/_{16}$ in. (+/- 1.6 mm) measured according to ASTM C 67.
10. Warpage: Consistent plane of plus 0 in., minus $^{1}/_{16}$ in. (+0, -1.6 mm).
11. Variation of Shape from Specified Angle: Plus or minus 1 degree.
12. Tensile Bond Strength: Not less than 150 psi (1.0 MPa), before and after freeze-thaw testing, when tested per modified ASTM E 488. Epoxy steel plate with welded rod on a single brick face for each test.

13. Freeze and Thaw Resistance: No detectable deterioration (spalling, cracking, or chafing) after 300 cycles when tested in accordance with ASTM C 666 Method A or B.

14. Modulus of Rupture: Not less than 250 psi (1.7 MPa) when tested in accordance with ASTM C 67.

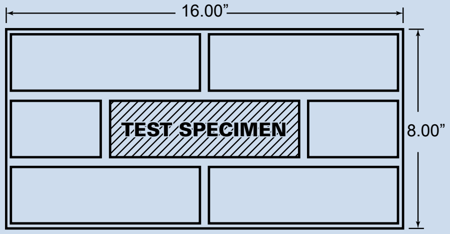
15. Chemical Resistance: Provide brick that has been tested according to ASTM C 650 and rated "not affected."

16. Surface Coloring: Brick with surface coloring shall withstand 50 cycles of freezing and thawing per ASTM C 67 with no observable difference in applied finish when viewed from 20 ft (6 m).

17. Back Surface Texture: **[Scored], [Combed], [Wire roughened], [Ribbed], [Keybacked], [Dovetailed]**.

Test sample size and configuration shall conform to the following parameters in order to validate compliance by brick manufacturer with PCI Standard for use in thin brick precast concrete systems:

1. Minimum number of tests specimens: Comply with appropriate specifications except for freeze-thaw and tensile bond strength tests on assembled systems.



Clarification of the test sample preparation.

2. Minimum number of test specimens for freeze-thaw and tensile bond strength tests: Ten (10) assembled systems measuring 8 x 16 in. (200 mm x 405 mm) long with the brick embedded into the concrete substrate (assembled system). The ten (10) assembled systems are divided into 5 Sample **A** assemblies and 5 Sample **B** assemblies. The precast concrete substrate shall have a minimum thickness of $2^1/_2$ in. (63 mm) plus the embedded brick thickness. The precast concrete shall have a minimum compressive strength of at least 5,000 psi (34.5 MPa) and 4 to 6% entrained air. The embedded brick coursing pattern for testing purposes shall be modular size brick on a half running bond pattern with a formed raked joint geometry of no less than $^3/_8$ in. (10 mm) wide and a depth no greater than $^1/_4$ in. (6 mm) from the exterior face of the brick. One brick from the center of each Sample **A** assembly shall be tested for tensile bond strength, Item #12. In place of anchor specified in ASTM E488, use $^3/_8$ in. (10 mm) minimum thickness steel plate of same size as single brick face bonded with epoxy to a single brick face for each tensile bond strength test. The steel plate shall have a centrally located pull-rod welded to the plate. Each Sample **B** assembly shall first be tested for freeze-thaw resistance, Item #13 and then one brick from the center of each Sample **B** assembly shall be tested for tensile bond strength, Item #12.

The appearance of clay product-faced precast concrete panels is achieved principally by the selected clay product, with type, size, and texture contributing to overall color. Also, the degree to which the clay product units are emphasized will depend upon the profile and color of the joint between units. The Brick Institute of America (BIA) recommends concave joints in all masonry projects. Due to forming requirements and material tolerances, it is preferable that joints between clay products be not less than $^3/_8$ in. (10 mm).

The joints between panels are usually butt joints. Corners are usually achieved by using brick returns equal to the length of the brick module. Another element in the appearance of the panel is the 5,000 psi (34.5 MPa) concrete visible in the joints. Hand-tooled joints may be simulated by form liners or joints may be tuckpointed after forms are stripped, however this may add to the cost and maintenance of the panel.

The contract documents should clearly define the scope of clay product sizes, coursing patterns, and placement locations. Both stack and running bond patterns have been used widely in precast concrete panels. These patterns can be interchanged with soldier courses, basket weave, or herringbone patterns. Running bond patterns are typically less costly and visually more appealing when courses start and finish with half or full brick lengths. This approach avoids cutting and allows matching adjacent spandrels or column covers. Also, providing a narrow strip of exposed concrete at the edges of the panel helps reduce the visual impact and potential difficulty in aligning brick joints between precast concrete units. Vertical alignment of joints, especially with stack bond, requires close clay product tolerances or cutting of brick to the same length.

Clay Product Properties

Physical properties of clay products vary depending on the source of clay, method of forming, and extent of firing. Because clay products are subject to local variation, the designer needs to obtain information on the specific clay product being considered to ascertain if the variations are acceptable.

As the temperature or length of the burning period is increased, clays burn to darker colors, and higher compressive strength and modulus of elasticity. In general, the modulus of elasticity of brick increases with compressive strength to a compressive value of approximately 5,000 psi (34.5 MPa); after that, there is little change.

Clay Product Selection

Clay product manufacturers or distributors along with precasters should be consulted early in the design stage to determine available colors, textures, shapes, sizes, and size deviations of clay products, as well as manufacturing capability for special shapes, sizes, and

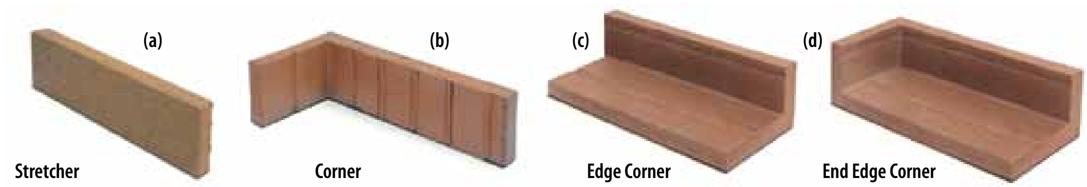


Figure 2 Thin brick units

tolerances. The specification should identify the color, size, and manufacturer(s) of the clay product. Usually the precast concrete producer buys the clay products and knows which products are able to conform to the PCI Standard for embedded brick in precast concrete.

PCI Standard thin brick veneer units $^1/_2$ to 1 in. (13 to 25 mm) thick are typically used and are available in various sizes, colors, and textures. Thin brick conforming to the PCI Standard are actually a tile and have lower water absorption than conventional brick. In addition, thin brick is less susceptible than conventional brick to freezing and thawing issues, spalling, and efflorescence.

Stretcher, corner, or three-sided corner units are typically available in a variety of color ranges (Fig. 2). The face sizes normally are the same as conventional brick and, therefore, when in place, yield the aesthetics of a conventional brick masonry wall with the superior performance of precast concrete.

The most common brick face size is the modular. The utility face size is popular for use in large buildings because productivity is increased, and the unit's size decreases the number of visible mortar joints, thus giving large walls a different visual scale. The PCI Standard contains most popular thin brick face sizes. Contact a local precaster or thin brick manufacturer's representative to determine availability of desired color or texture in the face sizes selected.

FBS and FBX are designations for facing brick types that control tolerance, chippage, and distortion. Type FBS is brick for general use in masonry while Type FBX is brick for general use in masonry where a higher degree of precision and lower permissible variation in size than permitted for Type FBS is required (see ASTM C 216). For thin-veneer brick units, Type TBS (Standard) is thin-veneer brick for general use in masonry while Type TBX (Select) is thin-veneer brick for general use in masonry where a higher degree of precision and lower permissible variation in size than permitted for Type TBS is required (see ASTM C 1088).

Some bricks (TBS or FBS, for example) are too dimensionally inaccurate for applications with precast concrete panels. Also, these bricks typically have high absorption rates that cause greater chances of efflorescing and freeze-thaw spalling. They conform to an ASTM specification suitable for site-laid-up applications, but they are not manufactured accurately enough to permit their use in a formliner (preformed grid) that positions bricks for a precast concrete panel. Tolerances in an individual TBX or FBX brick of ± 5/32 in. (±4 mm) or more cause problems for the precast concrete producer. Brick (TBX and FBX) are available from some suppliers to the close tolerances necessary for precasting. Close tolerances also can be obtained by saw-cutting each brick, but this increases costs substantially.

FBX brick may be split into soaps (half brick). Often only one side of the brick can be used as the facing veneer. The use of soaps will increase the thickness and weight of the panel. Whole bricks are not recommended for use in precast concrete because of the difficulty in adequately filling the mortar joints and the potential for freeze-thaw spalling plus the need to use mechanical anchors.

Figures 3 through 10 illustrate various projects with applications of brick-faced precast concrete panels.

The patterned façade on the museum (Fig. 3) is composed of bands of rusticated red brick accented by flamed white and black granite on the upper level. The 1-in.-thick (25 mm) bricks are cast in 9-in.- thick (225 mm) precast concrete panels. The bricks, some 600,000 in all, were rolled in sand before baking to give them a grainy finish. Most panels measure 10 x $28^1/_2$ ft (3 x 8.7 m) and contain 1,500 to 2,300 bricks per panel. The museum's horizontality was emphasized by raking the mortar joints between brick courses (Fig. 3 [b] and [c]). These figures also show the flat and corner panels with corner brick, as well as the close-ups of the façade patterns.

Figure 4 (a), (b) & (c) San Francisco Museum of Modern Art, San Francisco, California; Architect: Mario Botta, Design Architect: Hellmuth, Obata & Kassabaum, P.C. (HOK) Architect of Record. (Courtesy *Perretti & Park Pictures*)

The eight office and four assembly buildings in the 1.5 million sq. ft. (139,300 m^2) campus shown in Fig. 4 are clad with 6,882 thin brick-faced architectural precast concrete panels totaling 548,623 sq. ft. (50,967 m^2). The panels also clad four parking structures and the thin brick panels were brought into the main dining room in the assembly buildings. With multiple buildings under construction simultaneously, having brick-clad precast concrete panels produced off-site helped to reduce the on-site work required. That helped reduce the quantities of people, equipment, and materials on the job and ultimately created a more manageable, cleaner, and safer worksite.

The retail store in Fig. 5 features insulated thin brick-faced precast concrete panels highlighted with bands of 4 x 12 in. (100 x 300 mm) utility brick at the entry that alternate with the precast concrete tones. The panels were designed as shearwalls and have a light sandblast finish on the accent stripes. Brick-faced precast concrete panels were selected because the job schedule was able to be reduced by four months versus conventional masonry.

Brick-faced precast concrete panels were specified for the office complex in Fig. 6 over traditional brick construction for its cost efficiencies, speed of construction, and simplified logistics. The complex contains three structures: a 6-story office building, a 14-story office tower, and an 8-story parking structure that sits behind the two office buildings. The bricks are $^{5}/_{8}$ in. (16 mm) thick and are the skin of 6-in.-thick (150 mm) concrete panels. Designed as a nexus for a thriving high-tech corridor, the project connects Georgia Tech University with a burgeoning business and residential community. Architectural precast thin brick concrete panels helped mix city and university in a style that fits both neighborhoods.

The 950-vehicle parking structure (Fig. 7) was designed to address a university town's acute parking shortage while blending with the classical architecture of the campus buildings. A fast-track schedule took advantage of the ability to cast components, which included both structural and exterior façade components, before the completed design package was issued. Inset thin brick was used on upper-level panels, with the panels cast with the brick in place in the molds, creating a one-step operation. Lower floors feature panels with a limestone-like appearance that was achieved with a buff-colored finish, light sandblast texture, and detailed reveals. Only a few different sizes and shapes of precast concrete panels were required, speeding production and reducing costs by minimizing the number of molds. Material needs also were reduced by using the exterior precast concrete as both the façade and as loadbearing panels for the interior double tees.

The elementary school in Fig. 8 has loadbearing insulated sandwich wall panels with reddish-gray thin brick. Three inches of rigid extruded poly-

Figure 4 Merrill Lynch Hopewell Campus, Pennington, New Jersey; Architect: Thompson, Venulett, Stainback & Associates (TVS) .
(Photo: *Brian Gassel/TVS*)

Figure 5 Nordstrom Palm Beach Gardens; Palm Beach Gardens, Florida; Architect: Callison Architecture Inc. (Photo: *Vern Smith*).

Figure 6 Centergy at Technology Square Atlanta, Georgia; Architect: Smallwood, Reynolds, Stewart, Stewart & Associates Inc.;
(Photo: *Gabriel Benzur.*)

Figure 7 Hull Street Parking Deck, Athens, Georgia; Architect: Smallwood, Reynolds, Stewart, Stewart & Associates. (Photo: *Jim Roof.*)

Figure 8 Willow Creek Elementary School, Fleetwood, PA; Architect: AEM Architects, Inc., Reading, PA. (Photo: *AEM Architects, Inc.*)

styrene foam was sandwiched between the 3 in. exterior wythe and 4 in. interior wythe providing an R-value of 16. Conduit for exterior lighting and fixtures was cast into the troweled interior wythe. Interior walls were painted off-white and are the exposed surfaces of the classrooms. The precast façade was panelized to 14 ft (4.3 m) widths to minimize the number of joints and to optimize shipping efficiency.

The façade of the seven-level stadium in Fig. 9 features inlaid thin jumbo bricks on an insulated 3-2-3 (75-50-75) composite architectural precast system with limestone finished precast accents. The large column covers were sequentially cast which allowed them to be erected as one large piece versus three pieces. To enhance the visual expression, the arched entrances' thin brick were corbelled out.

The LEED Certified 400-bed suite-style university residence hall in Fig. 10 was designed to fit seamlessly onto an 80 year old Gothic campus. The cladding is composed of red and tan thin brick with precast concrete details such as attenuated fins that help break up its massing. The edge to edge insulated sandwich panels provide both the exterior wall and a trowel finished interior wall with an R-value of 26. Panels were 12 ft, 4 in. (3.7 m) tall x 30 ft long (9.1 m) with 3 ft (0.9 m) side returns. The interior wall was painted to match the drywall finishes of the space.

Ceramic Tile

Glazed and unglazed ceramic tile units should conform to American National Standards Institute (ANSI) A 137.1, which includes American Society for Testing and Materials (ASTM) test procedures and provides a standardized system to describe the commonly available sizes and shapes, physical properties, basis for acceptance, and methods of testing. Ceramic tiles are typically $^3/_8$ to $^1/_2$ in. (10 to 13 mm) thick, with a $1^1/_2$% tolerance on the length and width measurements. When several sizes or sources of tile are used to produce a pattern on a panel, the tiles must be manufactured on a modular sizing system in order to have joints of the same width.

Glazed units may craze from freeze-thaw cycles or the bond of the glaze may fail due to exposure to extreme environmental conditions. The body of a tile (not the glazed coating) must have a water absorption of less than 3% (measured using ASTM C 373) to be suitable for exterior applications. However, low water absorption alone is not sufficient to ensure proper selection of exterior ceramic tiles. As a result, when ceramic tile is required for exterior use, the tile manufacturer should be consulted for frost-resistant materials for exterior exposure. Glazes are covered by ASTM C 126 and tested in accordance with ASTM C 67.

Figure 9 Lucas Oil Stadium, Indianapolis, IN. Architect: HKS, Inc.. (Photo: *Gate Precast Company and HKS, Inc.*)

The architectural expression of the gallery and lecture halls of the School of Architecture in Fig. 11 (a) and (b) consists of colorful ceramic tile and a variety of outdoor spaces. The architect sculpted a pair of engaging forms, then wrapped them in red, orange, and yellow ceramic tile that gives the ensemble a hot, Latin flair. The vivid yellow and red structures are clad with 8 x 8 in. (200 x 200 mm) ceramic tiles with brilliant color variations. Tiles were recessed into the precast concrete, which produced a tightly sealed flush edge joint at the lightly sandblasted panel borders.

Figure 10 Opus Residence Hall at Catholic University of America, Washington, D.C. (Photo: *John C. Cole*)

The façades of the building in

Figure 11 (a) & (b) The Paul Cejas School of Architecture, Florida International University, Miami, Florida; Architect: Bernard Tschumi Architects, and BEA International (joint venture);

(Photos: *Thomas Delbeck*.)

Fig. 12 (a) and (b) are sheathed in precast concrete from the ground up. A number of panels are gull wing-shaped with wings containing windows angling outward at 45° on each end. These panels are 24 ft (7.5 m) long and 7 ft, 3 in. (2.2 m) high. The panels above ground level have 8 x 8 in. (200 x 200 mm) brick-colored tile inserts, adding a degree of contrast with the concrete while blending harmoniously with the predominately brick neighboring buildings. The use of clay tiles inset within the precast concrete panels provides a greater variety of color and texture than standard precast concrete panels. The clay tiles feature keybacks around which the concrete set, assuring permanent adherence. The end panels were formed with concrete returns to avoid miters or revealing actual panel thickness.

Inspired by glazed pottery, the designer for the hospital in Fig. 13 used glazed tile cast integrally into precast concrete panels to create a kaleidoscope of colors cascading across the facade. The architect employed a pixilation technique to precisely locate each tile to achieve his vision. In total, the project used 11 different glazed colors and 4 different tile sizes including glazed corner elements. The project's success was reliant on the close relationship between the design team and the precast producer to expand the limits of traditional architectural precast facades.

Terra Cotta

There is no ASTM standard for terra cotta, but units should meet the minimum requirements of ASTM C126 "Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick and Solid Masonry Units" or ASTM C212 "Specification for Structural Clay Facing Tile." It should have a minimum compressive strength of 8,000 psi with an absorption of less than 8% (24 hours soak) when tested in accordance with ASTM C 67. Architectural terra cotta is a custom-made product and, within certain limitations, is produced in sizes for specific jobs. Two thicknesses of terra cotta are usually manufactured: $1^1/_4$-in.-thick (32 mm) and $2^1/_4$ -in.-thick (56 mm) units. Sizes range from 20 to 30 in. (500 to 760 mm) for $1^1/_4$ in. units to 32 x 48 in. (810 x 1220 mm) for $2^1/_4$ in. units. Other sizes used are 4 or 6 ft x

2 ft (1.2 or 1.8 m x 0.6 m). Tolerances on length and width are a maximum of ± $^1/_{16}$ in. (±1.6 mm) with a warpage tolerance on the exposed face (variation from a plane surface) of not more than 0.005 in. (0.12 mm) per 1 in. (25 mm) of length. The use of terra cotta-faced precast concrete panels for restoration and new construction is illustrated in Figs. 14, 15, and 16. One of the earliest (early 1970s) terra cotta clad buildings is the 42-story office building, 575 Market Street, San Francisco, Calif. It has 9 ft (2.7 m) wide by 13 ft (4m) high L-shaped terra cotta-faced precast concrete panels. Seven equal $1^3/_4$ in. (44 m) thick terra cotta pieces were placed in a structural lightweight concrete backup in the $7^1/_2$ in. (190 mm) thick story high panels.

Figure 12 (a) & (b) Prospect Heights Care Center, Hackensack, New Jersey; Architect: Herbert Beckhard Frank Richlan & Associates; (Photos: *Norman McGrath Photograph.*)

Built in 1906, the six-story building in Fig. 14 (a) and (b) is considered one of San Francisco's architectural landmarks. For that reason, it was decided the building's terra cotta façade would be preserved on an otherwise all-new structure of slightly taller height. The terra cotta was taken off the building, piece by piece, and identified for subsequent reassembly on new precast concrete panels. Stainless steel wires were looped through the back ribs of the terra cotta pieces and projected into the backup concrete to anchor the pieces to the concrete.

Precast concrete panels with 1-in.-thick (25 mm) brick on 5-in.-thick (125 mm) concrete panels along with glazed terra cotta on the spandrels and mullions clad the nine-story building in Fig. 15 (a). Panels of light and deep sandblast finishes tied both systems together. See Fig. 15 (b) and (c) for a close-up of the terra cotta units.

For the sake of the traditional look of the historic Michigan Avenue streetwall's appearance, terra cotta-faced precast concrete was used for the 260,000 ft ^{2} (24,200 m^2) retail/cinema building (Fig. 16 [a]), encompassing

Figure 13 Mercy West Hospital, Green Township, Ohio; Architect: Ellerbe Becket (an AECOM Company), Minneapolis, Minnesota; (Photo: *Randy Wilson).*

Figure 14 (a) & (b) 88 Kearney Street. San Francisco, California; Architect: Skidmore, Owings and Merrill; (Photos: *Skidmore, Owings and Merrill San Francisco*.)

Figure 15 (a), (b) & (c) Sacramento County Systems and Data Processing, Sacramento, California; Architect: HDR Architecture Inc. formerly Ehrlich-Rominger; (Photos: *HDR Architecture Inc*.)

an entire block. The terra cotta pieces are a variety of shapes and sizes, with some flat, fluted, or round (Fig. 16 [b]). The backs of the extruded pieces were flat and holes were drilled in the terra cotta for insertion of stainless steel pins. The terra cotta units were placed in a mold and 10 in. (250 mm) of concrete was then cast to create a panelized system.

Design considerations

Variations in brick or tile color will occur within and between lots. The clay product supplier must preblend any color variations and provide units that fall within the color range specified and approved by the architect for the project. Defects such as chips, spalls, face score lines, and cracks are common with brick, and the defective units should be culled from the bulk of acceptable units by the clay product supplier according to the architect's requirements and in accordance with applicable ASTM specifications. Should minor damage occur to the clay product face during shipping, handling, or erection, field remedial work can be accomplished, including replacement of individual clay products. Units may be chipped out and new units installed using an epoxy, dry-set, or latex portland cement mortar.

The clay product surfaces are important in order to bond to the backup concrete. Textures that offer a good bonding surface include:

- Scored finish, in which the surface is grooved (ribbed) or dovetailed (keybacked) as it comes from the die.

Figure 16 (a) & (b) 600 North Michigan Avenue, Chicago, Illinois; Architect: Beyer Blinder Belle, Design Architect; and Shaw and Associates, Architect of Record.

- Combed finish, in which the surface is altered by parallel scratches.
- Roughened finish, which is produced by wire cutting or wire brushing to remove the smooth surface or die skin from the extrusion process.
- A brick wire cut (through extruded holes in whole bricks) to provide two (half) soaps.

With thin- and half-brick units, no metal ties or weeps are required to attach them to the concrete because adequate bond is achieved. In general, clay products that are cast integrally with the concrete have bond strengths exceeding that obtained when laying units in the conventional manner (clay product to mortar). In pullout tests, the brick fails or shears before it pulls out of the concrete. It is necessary, however, to be careful not to entrap air or excess water-caused voids. These voids could reduce the area of contact between the units and the concrete, thereby reducing bond. Half bricks with a water absorption of 6 to 9% obtained by five-hour boiling provide good bonding potential. Thin bricks should have a water absorption less than 6% per the PCI Standard.

Half bricks with an initial rate of absorption (suction) of less than 30 g /30 in.^{2} per min (30 g /194 cm^2 per min), when tested in accordance with ASTM C 67, are not required to be wetted. However, brick with high suction or with an initial rate of absorption in excess of 30 g /30 in.^{2} per min should be wetted prior to placement of the concrete. This will reduce the amount of mixture water absorbed and improve bond. Unglazed quarry tile

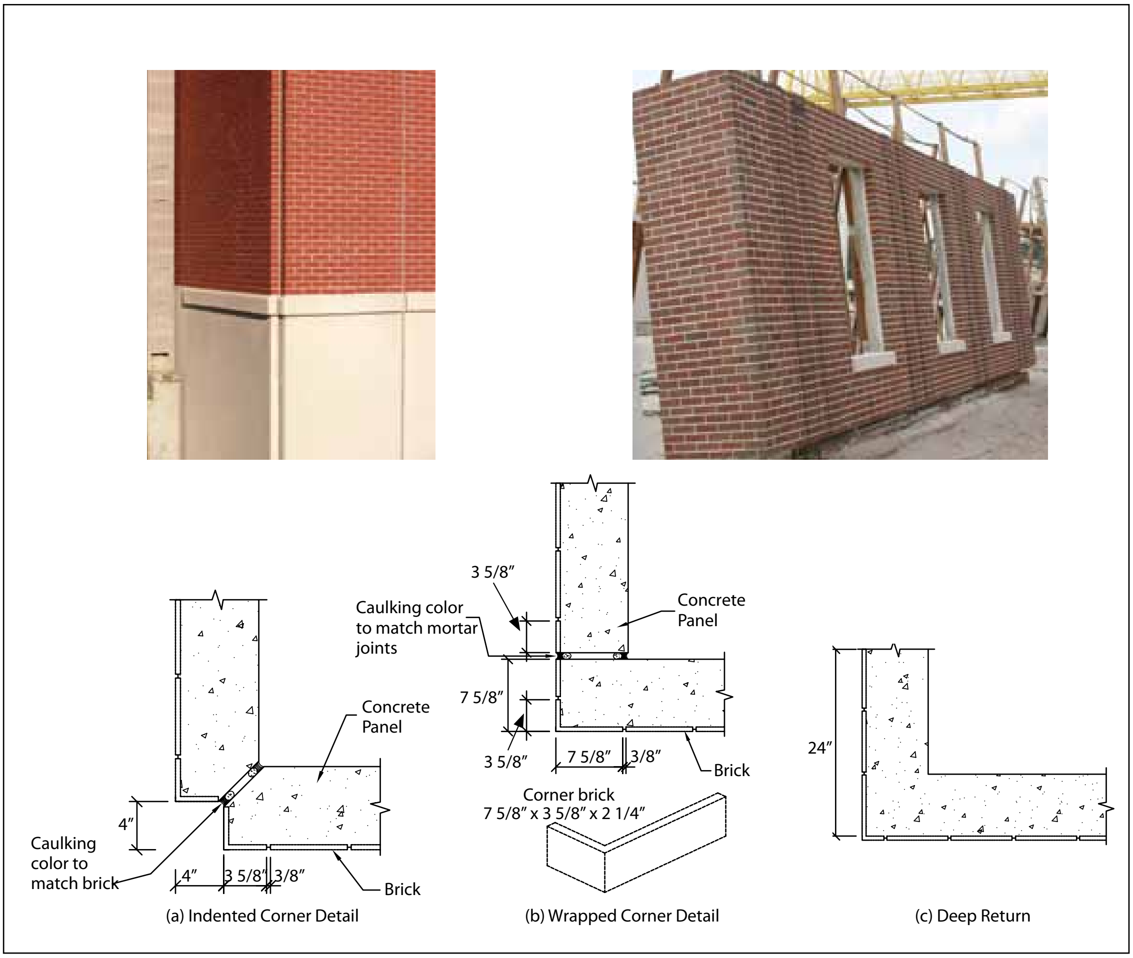


Figure 17 Corner details. (Photos: *Gate Precast Company*.)

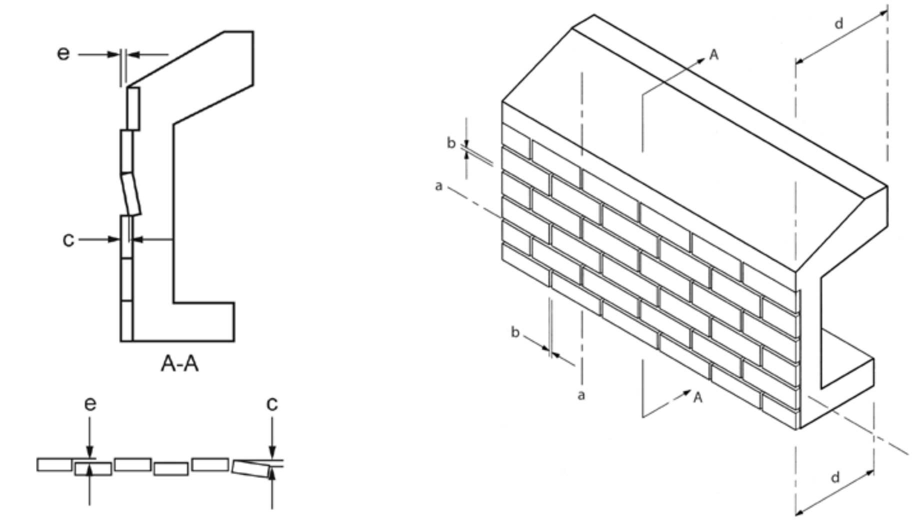
and frost-resistant glazed wall tiles generally do not need to be wetted. Terra cotta units should be soaked in water for at least one hour prior to placement to reduce suction and they should be damp at the time of concrete placement.

Because of the differences in material properties between the facing and concrete, clay product-faced concrete panels may be more susceptible to bowing than homogeneous concrete units. However, panel manufacturers have developed design and production procedures to minimize bowing.

Figure 19 Placing units in form liner (Photo: *Gate Precast Company*.)

Three types of corner details may be used: (1) indented (Fig. 17 [a]); (2) wrapped (Fig. 17 [b]); or (3) deep return (Fig. 17 [c]). Brick mortar joints should be concave (cove). At reveals and at the top and bottom of inset areas, the concrete should cover the edges of the brick units (Fig. 18). The designer also needs to pay special attention to where the joints between concrete panels are located, which is a departure from the use of traditional brick masonry.

In the development of the contract documents, using thin brick precast concrete panels provides a simplification of detailing over hand set masonry. The system avoids intricate flashing, masonry support, and masonry anchoring requirements that would be necessary with conventional construction to achieve layering and relief features.



a = Alignment of mortar joints:
Jog in alignment ... 1/8 in. [± 3 mm]
Alignment with panel centerline ... ± 1/8 in. [± 3 mm]

b = Variation in width of exposed mortar joints ... ± 1/8 in. [± 9 mm]

c = Tipping of individual bricks from the panel plane of exposed brick surface – 1/4 in. [–6 mm] ≤ depth of form liner joint

d = Exposed brick surface parallel to primary control surface of panel ... + 1/4 in., – 1/8 [+ 6 mm, –3 mm]

e = Individual brick step in face from the panel plane of exposed brick surface – 1/4 in. [–6 mm] ≤ depth of form liner joint

Figure 20 Tolerances for brick-faced architectural elements. Note: These tolerances also apply to ceramic tile and terra cotta.

Production and Construction Considerations

Clay product-faced units have joint widths controlled by locating the units in a suitable template or grid system set out accurately on the mold face (Fig. 19). Common grid systems generally consist of an elastomeric (or rubber) form liner or a plastic form liner. Liner ridges are typically shaped so that joints between units simulate concave-tooled or raked (flat) joints and should be considered with respect to temperate zones and aesthetics.

Occasionally individual clay units can float out of place or be damaged after casting. These units can be easily replaced or repaired by chipping out the undesired unit, preparing the concrete substrate, and attaching a new piece using epoxy. The joints can then be cosmetically repaired to match the field.

Tolerances for brick-faced precast concrete panels are shown in Fig 20. The number of bricks that could exhibit any misalignments should be limited to 2% of the bricks on the panel.

Tiles, measuring 2 x 2 in. (50 x 50 mm) or 4 x 2 in. (100 x 50 mm), may be supplied face-mounted on polyethylene or paper sheets and secured to the mold by means of double-faced tape or a special adhesive.

The space between the tiles is filled with a thin grout and then the backup concrete is placed prior to initial set of the grout. Figure 21 shows a project that uses 2 x 2 in. (50 x 50 mm) tiles that have been placed with the method described. For the best appearance, narrow tile joints should be filled from the front, particularly if cushion-edged tiles are used.

Figure 21 The Nikko Hotel, San Francisco, California; Architect: Patri-Merker Architects formerly Whisler-Patri. (Photo: *Patri-Merker Architects.*)

AIA Learning Units

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Instructions

Review the learning objectives below.

Read the AIA Learning Units article.

Answer the 11 questions at the end of the article and submit to PCI. Submittal instructions are provided on the Learning Units form. You will need to answer at least 80% of the questions correctly to receive the 1.0 HSW Learning Units associated with this educational program. You will be notified when your Learning Units are submitted to AIA.

Learning Objectives:

1. Define what thin-bricks and other clay products are.
2. Explain how thin-bricks and clay products are used in precast concrete.
3. Describe the benefits of using thin-brick veneers with precast concrete.
4. Explain the specification and requirements when using clay products with precast concrete.

Ascent 2012 – Clay Product-Faced Precast Concrete

Name (please print): ______________________________

Company Name: ______________________________

Address: ______________________________

City: ____________________ **State:** __________ **Zip:** __________

Phone Number: __________ **Email Address:** ____________________

Title: ______________________________

Background (circle one): Architect – Engineer – Business – Marketing/Sales – Finance – Other

To receive credit, please submit completed forms to:
Attn: Education Dept. - Alex Morales, Fax (312) 361-8079, Email amorales@pci.org

1. Clay product-faced precast concrete panels are designed considering the structural action of the face veneer.
   a. True
   b. False

2. The standard to be specified for thin brick is:
   a. TBX
   b. FBX
   c. PCI Standard

3. The minimum tensile bond strength of brick to precast both before and after freeze-thaw testing is:
   a. 100 psi
   b. 150 psi
   c. 200 psi

4. What patterns can be used with thin brick?
   a. Stack
   b. Running bond
   c. Basket weave
   d. Herringbone
   e. All of the above

5. What is the minimum thickness of thin brick used on precast concrete?
   a. $^{3}/_{8}$ in.
   b. $^{1}/_{2}$ in.
   c. $^{3}/_{4}$ in.
   d. 1 in.

6. Thin brick face sizes are the same as conventional brick.
   a. True
   b. False

7. The height and length of precast panels should be multiples of nominal individual masonry unit heights and lengths less the thickness of two mortar joints.
   a. True
   b. False

8. The body of a ceramic tile should have an absorption less than:
   a. 3%
   b. 4%
   c. 5%
   d. 6%

9. Architectural terra cotta should meet the requirements of which standards?
   a. ANSI A 137.1 and ASTM C 67
   b. ASTM C 67 and ASTM C 126
   c. ASTM C126 and ASTM C212

10. Which textures provide thin brick with a good bonding surface?
    a. Scored finish
    b. Combed finish
    c. Roughened finish
    d. All of the above

11. The number of bricks on a panel that could exhibit any misalignment on a panel should be limited to:
    a. 1%
    b. 2%
    c. 3%

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  April 24 and 26, 2012
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  May 22 and 24, 2012
- **Designing for Anti-Terrorism Force Protection with Precast Concrete**
  June 26 and 28, 2012

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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.

In-Person Learning Opportunities

Seminars

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 School**
  Level I/II
  May 7-9, 2012, Nashville, Tenn.
  August 29-31, 2012, Chicago, Ill.
  Level III
  May 9-12, 2012, Nashville, Tenn.
  CFA/IES
  May 7-9, 2012, Nashville, Tenn.
  CCA
  May 10, 2012, 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.

PCI-Certified Plants

(as of March 2012)

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, C3A**
Hanson Pipe and Precast Southeast, Pelham (205) 663-4681 .... **B4, C4**
Standard Concrete Products, Theodore (251) 443-1113 .... **B4, C2**

ARIZONA

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

ARKANSAS

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

CALIFORNIA

Bethlehem Construction, Inc., Shafter (661) 391-9704 .... **C3A**
Clark Pacific, Fontana (909) 823-1433 .... **A1, C3A, G**
Clark Pacific, 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**
Coreslab Structures (L.A.) Inc., Perris (951) 943-9119 .... **A1, B4, C4A**
CTU Precast, Olivehurst (530) 749-6501 .... **C3**
Hanson Structural Precast, Irwindale (626) 962-8751 .... **C4**
KIE-CON, Inc., Antioch (925) 754-9494 .... **B4, C3**
Mid-State Precast, L.P., Corcoran (559) 992-8180 .... **A1, C3A**
StructureCast, Bakersfield (661) 833-4490 .... **A1, B3, C3A**
Universal Precast Concrete, Inc., Redding (530) 243-6477 .... **A1**
US Concrete Precast Group /dba Pomeroy, Perris (951) 657-6093 .... **B4, C2A**
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 .... **B4, C4**
Rocky Mountain Prestress LLC, Denver (303) 480-1111 .... **A1, AT, C3A**
Rocla Concrete Tie, Inc., Denver (303) 296-3505 .... **C2**
Stresscon Corporation, Colorado Springs (719) 390-5041 .... **A1, B4A, C4A**
Stresscon Corporation, Dacono (303) 659-6661 .... **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, C4A**
Florida Precast Industries, Inc., Sebring (863) 655-1515 .... **C2**
Florida Rock and Sand Prestress Precast Co., Inc., Florida City (305) 247-9611 .... **B3, C3**
Florida Rock and Sand Prestress Precast Co., Inc., Miami (305) 247-9611 .... **B3**
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, C3**
Oldcastle Precast Jacksonville (904) 768-7081 .... **C1**
South Eastern Prestressed Concrete, Inc., West Palm Beach (561) 793-1177 .... **B3, C3**
Stabil Concrete Products, LLC, St. Petersburg (727) 321-6000 .... **A1**
Standard Concrete Products, Inc., Tampa (813) 831-9520 .... **B4, C3**
Stress-Con Industries, Inc., Fort Myers (239) 390-9200 .... **B3**
Structural Prestressed Industries Medley (305) 556-6699 .... **C4**

GEORGIA

Atlanta Structural Concrete Co., Buchanan (770) 646-1888 .... **C4A**
ConArt Precast, LLC, Cobb (229) 853-5000 .... **A1, AT, C3**
Coreslab Structures (ATLANTA) Inc., Jonesboro (770) 471-1150 .... **C3A**
Gulf Coast Pre-Stress, Inc., Jonesboro (228) 234-7866 .... **B4**
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 .... **C2A**
Tindall Corporation, Conley (800) 849-6383 .... **C4A**

HAWAII

GPRM Prestress, LLC, Kapolei (808) 682-6000 .... **A1, B3, C4**
GPRM Prestress, LLC, Puunene (808) 682-6000 .... **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, 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**
Spancrete of Illinois, Inc., Crystal Lake (815) 459-5580 .... **C2**
St. Louis Prestress, Inc. Glen Carbon (618) 656-8934 .... **B3, B3-IL, C3**
Utility Concrete Produ,cts, 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 Specialties, ,Inc., Monroeville (260) 623-6131 .... **A1**
StresCore, Inc., South Bend (574) 233-1117 .... **C2**

IOWA

Advanced Precast Co., Farley (563) 744-3909 .... **C1A**
Andrews Prestressed Concrete, Inc., Clear Lake (641) 357-5217 .... **B4, C4**
IPC, Inc., Iowa Falls (515) 243-5118 .... **A1, B4, B4-IL, C4A**
MPC Enterprises, Inc., Mount Pleasant (319) 986-2226 .... **A1, C3A**
PDM Precast, 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**
Waffle-Crete International, Inc., Hays (785) 625-3486 .... **C3A**

KENTUCKY

Bristol Group, Inc., Lexington (859) 233-9050 .... **C3**
de AM - RON Building Systems LLC, Owensboro (270) 684-6226 .... **B3, C3A**
Gate Precast Company, Winchester (859) 744-9481 .... **A1**
Prestress Services Industries LLC, Lexington (260) 724-7117 .... **B4, B4-IL, C4A**
Prestress Services Industries LLC, Lexington (859) 299-0461 .... **A1, B4, C4A**
Prestress Services Industries LLC, Melbourne (859) 441-0068 .... **B4, C3**

LOUISIANA

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**

MAINE

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

MARYLAND

Atlantic Metrocast, Inc., LaPlata (301) 870-3289 .... **B3, C1**
Larry E. Knight, Inc., Glyndon (410) 833-7800 .... **C2**
Oldcastle Precast Building Systems Div., Edgewood (410) 612-1213 .... **A1, C3A**

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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

MICHIGAN

Grand River Infrastructure, Inc., Grand Rapids (616) 534-9645 .... B4, C1
International Precast Solution, LLC, River Rouge (313) 843-0073 .... A1, B3, C3
Kerkstra Precast Inc., Grandville (800) 434-5830 .... A1, B3, C3A
Nucon Schokbeton / Stress-Con Industries, Inc., Kalamazoo (269) 381-1550 ..... A1, B4, C3A
Stress-Con Industries, Inc., Detroit (313) 873-4711 .... B3, C3
Stress-Con Industries, Inc., Saginaw (989) 239-2447 .... B4, C3

MINNESOTA

Crest Precast, Inc., La Crescent (507) 895-8083 .... B3A, C1A
Cretex Concrete Products North, Inc., Elk River (763) 545-7473 .... B4, C2
Fabcon, 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 Products, Albany (320) 845-2299 .... A1, C3A
Wells Concrete Products Co., 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
Rotondo Weirich Enterprises, Inc., Yazoo City (215) 256-7940 .... C1
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 Company, Ozark (417) 581-7009 .... C4
Prestressed Casting Company, Springfield (417) 869-1263 .... A1, C3A

MONTANA

Missoula Concrete Construction, Missoula (406) 549-9682 .... A1, B3, C3
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 (OM,AHA) Inc., LaPlatte (402) 291-0733 .... A1, B4, C4A
CXT, Inc., Grand Island (308) 382-5400 .... C2
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
High Concrete Group LLC, Buena (856) 697-3600 .... C3
Jersey Precast Corp., Hamilton Township (609) 689-3700 .... B4, C4
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 .... B1, 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
S & G Prestress Company, Leland (910) 397-6255 .... B4
S & G Prestress Company, Wilmington (910) 763-7702 .... B4, C3
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 .... C2
Fabcon LLC, Grove City (614) 875-8601 .... 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 LLC, Grove City (614) 871-2900 .... B4, C1
Prestress Services Industries of Ohio, LLC, Mt. Vernon (800) 366-8740 .... B4, C3
Prestress Services Industries of Ohio, LLC, Mt. Vernon (740) 393-1121 .... B3, C1
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
Tulsa Dynaspan, Inc., Broken Arrow (918) 258-1549 .... A1, C3

OREGON

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

PENNSYLVANIA

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 East, LLC, Mahanoy City (570) 773-2480 .... 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
Pittsburgh Flexicore Company, Inc., Donora (724) 258-4450 .... C2
Say-Core, Inc., Portage (814) 736-8018 .... C2
Sidley Precast, Youngwood (724) 755-0205 .... C3
Technopref Industries Inc., Royersford Plant, Royersford (450) 569-8043 .... B1, C1
U.S. Concrete Precast Group Mid-Atlantic, Middleburg (570) 837-1774 .... A1, C3A
Universal Concrete Products Corporation, Stowe (610) 323-0700 .... A1, C3A

SOUTH CAROLINA

Florence Concrete Products, Inc., Sumter (803) 775-4372 .... B4, C3A
Metromont Corporation, Greenville (864) 295-0295 .... A1, C4A
Parker Marine Contracting Corporation, Charleston (843) 723-2727 .... B2, C2
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
Metromont Corporation, LaVergne (615) 793-3393 .... A1, C4A
Mid South Prestress, LLC, Pleasant View (615) 746-6606 .... C3
Prestress Services Industries of TN, LLC, Memphis (901) 775-9880 .... B4, C3
Ross Prestressed Concrete, Inc., Bristol (423) 323-1777 .... B4, C3
Ross Prestressed Concrete, Inc., Knoxville (865) 524-1485 .... B4, C4
Sequatchie Concrete Service, Inc., Chattanooga (423) 867-4510 .... C2

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TEXAS

Coreslab Structures (TEXAS) Inc., Cedar Park (512) 250-0755 .... **A1, C4A**
CXT, Inc., Hillsboro (254) 580-9100 .... **B1, C1**
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**
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 .... **B4, C4A**
North American Precast Company, San Antonio (210) 509-9100 .... **A1, C4A**
Rocla Concrete Tie, Inc., Amarillo (806) 383-7071 .... **C2**
Tindall Corporation, San Antonio (210) 248-2345 .... **C2A**

UTAH

EnCon Utah, LLC, Tooele (435) 843-4230 .... **A1, B4, C3A**
Hanson Structural Precast Eagle, Salt Lake City (801) 966-1060 .... **A1, B4, C4A, G**
Harper Contracting, Salt Lake City (801) 326-1016 .... **B2, C1**
Owell Precast LLC, Bluffdale (801) 571-5041 .... **B3A, C3**
The Shockey Precast Group, LLC, Harriman (540) 667-7700 .... **C3**

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**
Rockingham Precast, Inc., Harrisonburg (540) 433-8282 .... **B4, C3**
Smith-Midland Corporation, Midland (540) 439-3266 .... **A1, B2, C3**
The Shockey Precast Group, Fredericksburg (540) 898-1221 .... **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) 921-8716 .... **B1**
CXT, Inc., Spokane (509) 921-7878 .... **C2**
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

Advance Cast Stone Co., Inc, Random Lake (920) 994-4381 .... **A1**
County Materials Corporation, Eau Claire (800) 729-7701 .... **B4**
County Materials Corporation, Roberts (800) 426-1126 .... **B4, C3**
International Concrete Products, Inc., Germantown (262) 242-7840 .... **A1, C1**
MidCon Products, Inc., Hortonville (920) 779-4032 .... **A1, AT, C1**
Spancrete, Inc., Green Bay (920) 494-0274 .... **B4, C4**
Spancrete, Inc., Valders (920) 775-4121 .... **A1, B3, C3A**
Stonecast Products, Inc., Germantown (262) 253-6600 .... **A1, C1**
Wausau Tile Inc., Rothschild (715) 359-3121 .... **AT**

WYOMING

VAE Nortrak North America, Inc., Cheyenne (509) 220-6837 .... **C2**

CANADA

ALBERTA

Armtec Limited Partnership, Calgary (403) 248-3171 .... **A1, B4, C4**

BRITISH COLUMBIA

Armtec Limited Partnership, Richmond (604) 278-9766 .... **A1, B4, C3**

MANITOBA

Armtec Limited Partnership, Winnipeg (204) 338-9311 .... **B4, C3A**

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**

MEXICO

PRETECSA, S.A. DE C.V., Atizapan De Zaragoza (011) 52-1036077 .... **A1, G**
Willis De Mexico S.A. de C.V., Tecate (011) 52-665-655-2222 .... **A1, C1, G**

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PCI-Qualified & PCI-Certified Erectors

(as of March 2012

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.

ARIZONA

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

ARKANSAS

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

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**
Gibbons Erectors, Inc., Englewood (303) 841-0457 .... **S2, A**
Rocky Mountain Prestress, Denver (303) 480-1111 .... **S2, A**
S. F. Erectors Inc., Elizabeth (303) 646-6411 .... **S2, A**

CONNECTICUT

Blakeslee Prestress, Inc., Branford (203) 481-5306 .... **S2**
Jacob Erecting & Construction LLC, Durham (860) 788-2676 .... **S2, A**

FLORIDA

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**
Florida Precast Industries, Sebring (863) 655-1515 .... **S1**
Gate Precast Erection Co., Jacksonville (904) 757-0860 .... **A**
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**
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**
ConArt Precast, LLC, Cobb (229) 853-5000 .... **S2, A**
Jack Stevens Welding LLP, Murrayville (770) 534-3809 .... **S2**
Precision Stone Setting Co., Inc., Hiram (770) 439-1068 .... **S2, A**
Rutledge & Son's, Woodstock (770) 592-0380 .... **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**
Spancrete of Illinois, Inc., Crystal Lake (815) 459-5580 .... **S2**

INDIANA

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

IOWA

Architectural Wall Systems Co., West Des Moines (515) 255-1556 .... **A**
Cedar Valley Steel, Inc., Cedar Rapids (319) 373-0291 .... **S2, A**
Topping Out Inc. / dba Northwest Steel Erection, Des Moines (800) 247-5409 .... **S2**

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KANSAS

Carl Harris Co., Inc., Wichita (316) 267-8700 .... S2, A
Crossland Construction Company, Inc., Columbus (620) 429-1414 .... S2, A
Ferco, Inc., Salina S1
Topping Out Inc. / dba Davis Erection Kansas City, Kansas City (800) 613-9547 .... S2

LOUISIANA

Lafayette Steel Erector, Inc., Lafayette (337) 234-9435 .... S2

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

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

MASSACHUSETTS

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

MINNESOTA

Amerect, Inc., Newport (651) 459-9909 .... A
Fabcon, Inc., Savage (952) 890-4444 .... S2
Hanson Structural Precast Midwest, Inc., Maple Grove (763) 425-5555 .... S2, A
Molin Concrete Products Company, Lino Lakes (651) 786-7722 .... S2, A
Wells Concrete Products Co., Wells (507) 553-3138 .... S2, A

MISSISSIPPI

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

MISSOURI

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

NEBRASKA

Moen Steel Erection, Inc., Omaha (402) 884-0925 .... 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

NEVADA

Cedco Commerical, LLC, Las Vegas (702) 361-6550 .... 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

NEW YORK

Arben Group LLC, Pleasantville (914) 741-5459 .... S2
Empire Constructors LLC, Pittsford (585) 586-1510 .... A
J.C. Steel Corp., Bohemia (631) 563-3545 .... A
Koehler Masonry, Farmingdale (631) 694-4720 .... S1
Oldcastle Building Systems Div. / Project Services, Manchester (518) 767-2116 .... S2, A
Oldcastle Building Systems Div. / Project Services, Selkirk (518) 767-2116 .... S2, A

NORTH CAROLINA

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

NORTH DAKOTA

PKG Contracting, Inc., Fargo (701) 232-3878 .... S2
Wells Concrete, Grand Forks (701) 772-6687 .... S2

OHIO

Ben Hur Constructionn Company, Fairfield (513) 874-9228 .... A
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
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

TENNESSEE

Hoosier Prestress, Inc., Brentwood (615) 661-5198 .... S2

TEXAS

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
OutWest C & E Inc., Bluffdale (801) 446-5673 .... S2, A

VERMONT

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

VIRGINIA

Sprinkle Masonry Inc., Chesapeake (757) 545-8435 .... A
The Shockey Precast Group, Winchester (540) 665-3253 .... S2, A
W. O. Grubb Steel Erection, Inc., Richmond (804) 271-9471 .... A

WASHINGTON

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

WISCONSIN

Modern Crane Service, Inc., Onalaska (608) 781-2252 .... S1
Spancrete, Valders (920) 775-4121 .... S2, A
Spancrete, Waukesha (414) 290-9000 .... S2, A
The Boldt Company, Appleton (920) 225-6127 .... S2, A

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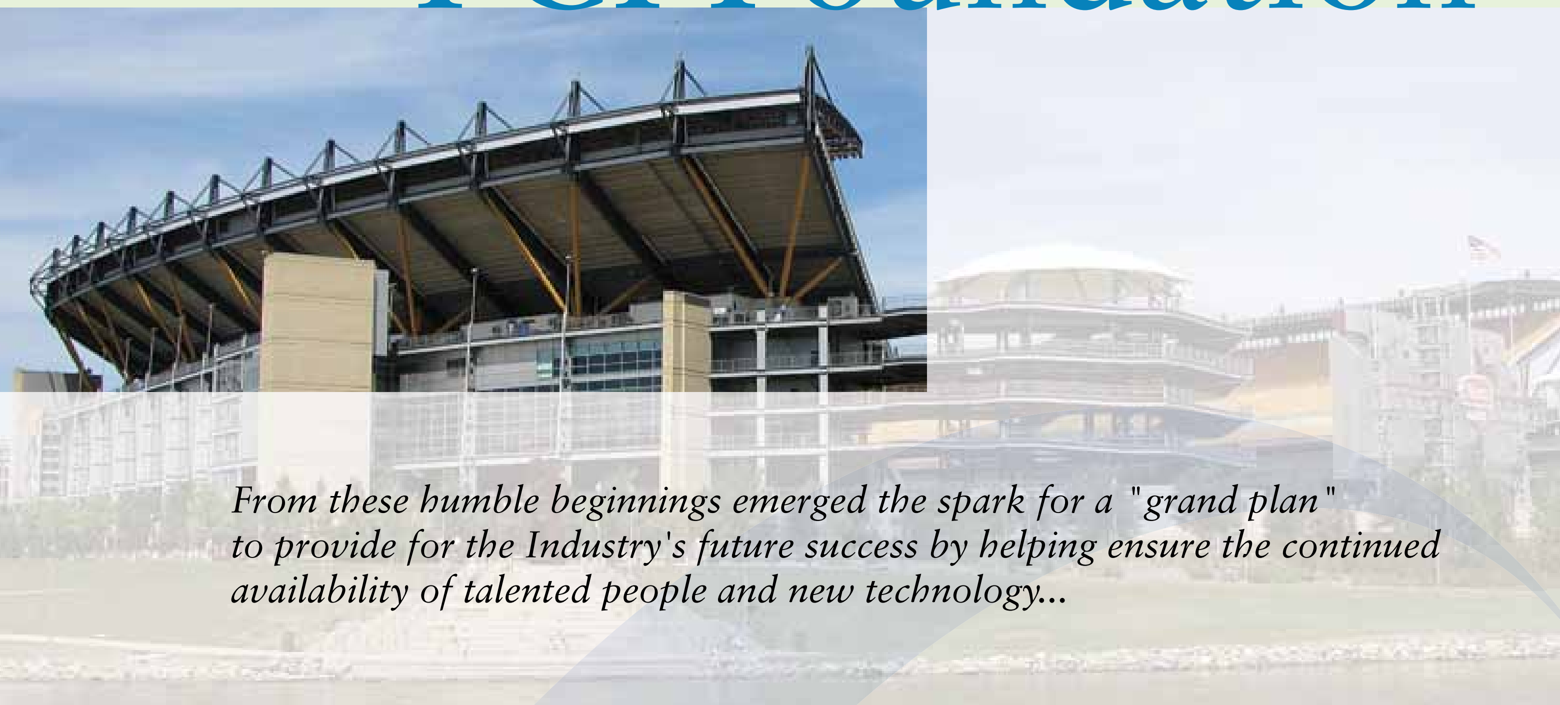

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