

# Safe, High-Performance, Sustainable Precast School Design

By Peter I. Finsen

*School design utilizing integrated architectural and structural precast and prestressed concrete components has gained greater acceptance recently for numerous reasons, including increasingly sophisticated owners and improved learning environments based on material benefits such as: sustainability, energy efficiency, indoor air quality, storm resistance, cost effectiveness (initial and life-cycle), durability and low maintenance. Safe, high-performance, sustainable school design provides physical facilities that improve learning environments while offering shelter from the storm, saving energy and resources, and delivering improved life cycle cost value.*

School administrators and designers are recognizing the numerous advantages that precast concrete architectural panels and structural systems can offer K-12 and higher education school projects. Precast buildings can greatly accelerate construction time to meet tight occupancy deadlines; provide competitive construction costs with significantly reduced lifecycle costs; and provide a variety of architectural finishes to blend with a campus' institutional look or create a cutting-edge modern style. And, an integrated precast concrete design can assist in providing safe, healthy, high-performance and sustainable learning environments.



Mallard Creek High School, Charlotte-Mecklenburg Schools, Charlotte, NC

## Safe School Facilities

Achieving a safe and secure school structure for owners and users provides key challenges for designers. Integrating these critical functional aspects while meeting aesthetic goals and educational programmatic needs, requires designers to remain up to date on new techniques and systems that can minimize the intrusion of security and safety elements in the overall plan. As security worries rise and Mother Nature continues to show her power, these concerns become key drivers for the safety of students.

Precast concrete designs can offer protection against fires, earthquakes, hurricanes, tornados and even explosive blasts when design and detailing are correctly applied. The requirements for achieving these goals must be taken into account early in the design process to maximize the effectiveness of precast concrete's capabilities against each of these issues.

### Fire Resistance

A key goal for the design team and the client is to protect the building from the multiple risks and losses caused by fire. A common misconception is that fire destroys by flames, which can

be suppressed by sprinklers. In practice, this oversimplification can leave both property and human life vulnerable during a fire. Precast concrete provides noncombustible construction that can help contain a fire within minimal boundaries. As a separation wall, precast concrete helps to prevent a fire from spreading throughout a building or jumping between structures.

An important aspect of dealing with fire endurance is to understand the benefits to the owner of a building in the proper selection of materials incorporated in the structure. These benefits fall into two areas: codes and economics. While code requirements must be met, designers typically have many options in the specification of materials and assemblies that meet these regulations. Economic benefits associated with increased fire endurance determined through a life-cycle cost analysis can include lower insurance rates, larger allowable gross area, and fewer stairwells and exits.<sup>1</sup>

A design approach that stresses compartmentalization offers a more

<sup>1</sup> Chapter 9.3.10. "Fire Resistance: Code and Economic Considerations." MNL-120-04; *PCI Design Handbook, Sixth Edition*.



Riverside High School, Greenville County Schools, Greer, SC

fundamental method to protect lives and property. Compartmentalization uses passive, noncombustible floors and walls, such as those made of precast concrete, to construct sections of the building as separate modules that confine fire to a specific area. Once constructed into the building, these passive protectors will protect the building throughout its life.

Noncombustible compartmentalization, combined with an inherently fire resistant/ tolerant structural frame, provides the best combination of economics and protection. When this passive design combines with other safety measures, including sprinklers and early-warning detection systems, a balanced design approach is achieved.

A variety of precast concrete components can be used in creating a complete passive, fire resistant design. Foremost among these are: insulated sandwich wall panels, columns and beams and double tees or hollow-core slabs. A total-precast concrete system provides an effective design for minimizing fire damage and containing the effects within the smallest space possible for the longest time.

#### Earthquake Resistance

Precast concrete can be designed to resist seismic events and recent advancements in connection approaches provide additional design options. Earthquakes in Guam, US, (Richter scale 8.1); Manila, Philippines (Richter scale 7.2); and Kobe, Japan (Richter scale 6.9), have subjected precast concrete buildings, using both architectural cladding and structural components, to some of nature's deadliest forces. During the 1994 Northridge, CA., earthquake (Richter scale 6.8), in which damage was estimated at \$20 billion, most engineered structures within the affected region performed well, including structures with precast concrete components.

The key reason designers have gravitated toward precast concrete components is because they can span long distances between attachments to the main structure. Design methods and details have been developed to accommodate these applications in seismic areas. The Precast/Prestressed Concrete Institute (PCI) has worked to help create new design solutions that provide more effective responses to seismic events. A 10-year study by the Precast Seismic Structural Systems (PRESSSS) Research Program produced three new approaches that have been or are in the process of being codified.<sup>2</sup>

#### Wind Resistance (Tornados and Hurricanes)

In most areas of the United States using the International Building Code, the earthquake loading will be more critical than wind. But wind loads should be checked, and more emphasis today is being put on designing structures to withstand tornado and hurricane impacts, certainly in coastal areas where they are being addressed through supplemental codes and other local requirements. Precast concrete structural systems and architectural panels provide significant benefits in meeting wind-resistance needs.

In regions of the country where tornados can wreak havoc on school buildings, precast concrete designs can provide a durable, wind-resistant structure. Building-envelope requirements often lead to facilities constructed with precast concrete wall panels and double-tee girders for roof structures. Historically these have provided a cost-effective method of construction. Specifying certified precast concrete ensures a known quality-control process will be used (a requirement) and construction time can be better minimized and quantified.

The design of "safe rooms", which may qualify for FEMA grant funding, go above and beyond the requirements of standard building design. Depending on the geographic location,

design wind speeds range from 130 mph to 250 mph, and the facilities are required to meet specific flying-debris or missile impact criteria. Code requirements for Safe Rooms include FEMA 361 – Design & Construction Guidance for Community Safe Rooms, ICC-500 Standard for Design & Construction of Storm Shelters, and the locally adopted building code.<sup>3</sup>

A safe room's main function is to protect occupants from extreme environmental events, but the secondary use can be just as important to the owner, especially in mitigating budget costs. Secondary uses of safe rooms may include gymnasiums, cafeterias, band rooms, classroom buildings, park facilities and community centers. Integrating a secondary use provides multiple benefits and safe rooms integrated into a larger facility with multi-uses will reduce the overall project cost, versus a standalone safe room.

The devastating impact of recent hurricanes, notably Katrina and Rita, have put a spotlight on designing to withstand the highest levels of these forces, which are more complex than those associated with tornados. Hurricanes produce not only high winds but also forces associated with the impact from high waves and immense amounts of water overwhelming a structure.

High winds can be dealt with similarly to those in tornados and do not pose a substantial risk for buildings built of precast concrete. Examination of projects exposed to the high winds of Hurricane Katrina indicated that wind loads for precast concrete buildings were well accounted for. Wind-borne debris creates the largest problem and results in only chipping or cracking in some instances at the high end of the wind speeds. Precast concrete components can help to withstand these forces if designers take into account all of the actions involved and how the components must react to them. The factors that designers must consider in addition to high winds include:

<sup>2</sup> "Precast Seismic Innovations Aid Designs Across Nation," *Ascent*, Winter 2000, pp. 16-23.

<sup>3</sup> "Designing School Safe Rooms", *Ascent*, Summer 2011, pp. 38-42.

surge, scour, buoyancy and structure orientation.<sup>4</sup>

Concrete is not damaged by water. In fact, concrete that does not dry out continues to gain strength in the presence of moisture. Concrete submerged in water absorbs small amounts of water over long periods of time, and the water does not damage the concrete. In flood-damaged areas, concrete buildings are often salvageable. Concrete will only contribute to moisture problems in buildings if it is enclosed in a system that does not let it breathe or dry out, and moisture is trapped between the concrete and other building materials.

While not typically addressed in K-12 school design, in today's environment of enhanced risk, some facilities require protective design (external blast resistance) and the management of risk. There are many design options available to reduce the risk to any building and features can be incorporated into precast concrete panel systems to accommodate blast loading. Economically feasible design for antiterrorism/ force protection (AT/FP) requires an integrated approach encompassing many aspects, including siting, operation programming of interior spaces and the use of active and passive security measures using provisions of both technology and human involvement.

The objective of blast-resistant design is to provide an acceptable level of safety to building occupants in the event of an explosion. Considerable damage is usually acceptable as long as components remain attached to the building and the building does not experience a progressive collapse. Planning must include all involved members of the design team - owners, architects, structural engineers, and blast consultants. They must agree upon the blast forces to be withstood as well as the risk and vulnerability assessment to the occupants and the protection levels that can be achieved within budget.<sup>5</sup>

4 Chapter 3.2.2, "Wind Loads," MNL-120-04: *PCI Design Handbook, Sixth Edition*.

5 DN-14-04: *PCI Designer's Notebook: Blast Considerations, Introduction*, p. 2.

### High Performance School Design

High performance schools are facilities that improve the learning environment while saving energy, resources and money. "High performance school" refers to the physical facility - the school building and its grounds. A well-designed facility can enhance performance and make education a more enjoyable and rewarding experience. Creating a high performance school requires an integrated "whole building" approach to the design process. Key systems and technologies must be considered together from the beginning of the design process, and optimized based on their combined impact on the comfort and productivity of students and teachers.<sup>6</sup>

High performance design can have a positive effect on health and comfort, and design strategies such as daylighting have been shown to enhance student learning. Good indoor air quality is essential for teacher and student health. Good design also produces more comfortable environments with proper lighting, air temperature, humidity, and noise levels. This reduces distractions and creates environments where students and teachers can see clearly, hear accurately and not feel too warm or too cold. Precast concrete designs are material efficient and can aid in producing schools that are thermally, acoustically and energy efficient. They require less maintenance and provide greater durability.

These increased efficiencies save money on maintenance and utilities, and healthier environments can bring additional savings by lowering absenteeism and increasing funding based on Average Daily Attendance. These financial, health and productivity benefits are the result of integrated design - understanding how building elements affect one another to optimize the performance of the entire school.

### Sustainable School Environments

The characteristics of high

6 "High Performance Schools", EPA, IAQ Design Tools for Schools, Accessed August 4, 2011, <http://www.epa.gov/iaq/schooldesign/highperformance.html>



St. Vincent DePaul Elementary School  
Long Beach, MS

performance schools mesh well with the concepts of sustainable design and precast concrete components can aid designers in meeting requirements for environmentally friendly, green design. In general, sustainability is considered to mean development that meets present needs without compromising the ability to meet the needs of future generations. The goal is to use building materials and energy resources in ways that will minimize their depletion or not restrict their ability to be used by future generations.

Today's approach extends beyond the ability to renew or recycle resources to examine the embodied energy required to make use of that material. This accounting practice encompasses all the energy necessary to manufacture, deliver and install the product, including fuel to extract materials, finish them and transport them to the site. And, the concept balances environmental impact with cost-effectiveness.

While other building materials may have to alter their configurations or properties to be applicable to sustainable structures, precast concrete's inherent composition allows it to naturally achieve sustainability. It contributes by incorporating integrated design, using materials efficiently, and reducing construction waste, site disturbance, and noise.<sup>7</sup>

### Precast Components and Innovation

Nowhere is the recognition of these benefits more apparent than in Greenville County, S.C., where the school district used innovative financing and construction methods to undertake a comprehensive \$1-billion

7 Chapter 5, Section 5.4, "Sustainability," MNL-122-07: *PCI Architectural Precast Concrete Manual, Third Edition*.



Tucker High School, Dekalb County Schools, Tucker, GA

rebuilding and expansion program. The program, completed in 2008, involved renovation, expansion and new construction of 70 schools to better serve the district's 71,000 students.

Such a dynamic plan required a thorough examination of new technologies, designs and materials. As a result, the program is using more than 1 million square feet of precast concrete insulated wall panels. The panels feature a layer of R-11 insulation sandwiched between two layers of concrete. The inner layer forms the school's interior wall and provides thermal mass to help reduce energy costs, while the exterior of each panel serves as the architectural façade.

Two innovative methods were used on different schools to connect the inner and outer wythes of concrete, making the panels nonconductive so they provide a continuous insulation profile. As a result, walls don't generate hot or cold spots along the perimeter, producing thermal comfort and energy efficiency. Additionally, electrical conduit and switch boxes were cast into the wall panels at the precast manufacturing plant, eliminating some on-site construction time.

Multistory wall panels were used in both load-bearing and non load-bearing applications in the district, with a range of aesthetic designs. Integrally cast thin-set brick provided a traditional masonry look, appropriate community scale and a higher performance wall system than traditional masonry construction techniques. Designers combined this system with other aesthetic applications, including sandblasted textures, reveals, medallions and pigmented concrete mixes.<sup>8</sup>

<sup>8</sup> "Precast Concrete Gets High Marks for K-12 Schools," Schools of the 21st Century, Architectural Record, January 2007, pp. 60-63.

### Components Aid Design Economy

A number of precast concrete components are used in school projects, and they offer a "kit of parts" capability that allows them to be used in a variety of ways. The most commonly used types of precast concrete components are:

- Wall panels, either non-load or load bearing, often with an interior (sandwiched) layer of insulation.
- Hollow-core and double-tee floor/ceiling/roofing panels.
- Columns and beams, often used in large-volume assembly areas (gymnasiums, theaters, cafeterias) to accommodate the longer spans required.

Even more advantages are achieved when the components are combined in a 'total-precast' concrete system, which integrates the building's structural frame with the architectural façade and thermal envelope.

### First-Cost and Lifecycle Cost Effectiveness

Precast concrete components save money in many ways, both for capital construction budgets and long-term operational needs. Savings include costs often hidden within the overall construction budget and create advantages that continue throughout the building's lifecycle.

Precast concrete is prefabricated at off-site manufacturing facilities, providing more quality control with fewer required site inspections. Construction of integrated precast elements eliminates months from the construction schedule, resulting in less time to carry financial bonds, lower contractor overhead costs and risk, elimination of expenses for masonry scaffolding, site storage and site waste, and reduced subcontractor costs due to a greater level of responsibility being given to a single-source supplier.

A total precast concrete system can help reduce insurance costs due to its inherent fire and storm resistance. It also saves cost and offers

environmental friendliness by combining several components into a single panelized system. Combining the savings from the construction budget with those in the long-term operating budgets produces a dramatic advantage. A precast concrete system is estimated to save between 5 and 8 percent of overall costs during the school's lifetime compared to a masonry building.

### Precast Accelerates Schedules

School buildings are complex projects, with a wide range of programmatic needs and active community involvement. That combination creates a tight restraint on construction schedules, as the facility must be ready when the fall school bell rings—and it's ringing earlier than ever. Precast concrete components can accelerate the construction schedule to ensure early delays don't impact the final deadline.

For instance, it takes significantly less time to design a precast concrete school than one built of masonry, due to the lessened detail required for precast's panelized system and the ability to quickly replicate components for each floor or wing. Precast manufacturers offer a high degree of engineering expertise and design assistance to speed the process further.

Prefabrication allows components to be manufactured early in the construction process with just-in time delivery to the construction site to accelerate construction sequencing. Fabrication can occur while permitting, site prep and foundation work progress, giving contractors a significant head start before the site is available. Once the foundation is complete, precast components typically can begin erection immediately. And, as the single-source supplier for a large portion of the structural system and building envelope, precasters can help to maintain the critical-path schedule.

Because precast components are fabricated under factory-controlled conditions, adverse winter weather does not impact the production schedule or product quality. Precast concrete can be erected in almost all weather

conditions, eliminating unknown factors and ensuring tight timetables will be met. Precast construction can also aid in improved construction site safety. Less on-site trades are needed to erect the structure and thermal enclosure. Once erected, other trades can work in more productive conditions.

Precast concrete insulated sandwich panels create a finished interior wall that avoids the time and cost of insulating, fireproofing, furring and dry-walling. The wall is highly durable and vandal-resistant, making it an ideal option, especially in high-use areas such as gymnasiums and pools.

Precast's just-in-time delivery and its array of efficiencies creates a speed advantage that grows throughout the construction process, saving costs and meeting deadlines. The use of precast concrete has been estimated to cut one-third from the required timetable.

### **Aesthetic Diversity Expands Options**

Often school administrators want their facilities to project a strong, secure image featuring a traditional appearance that incorporates such materials as brick or limestone. Others desire the school to blend with existing campus buildings, the neighborhood or have a cutting-edge style. Precast concrete components can be designed to respond to each of these needs in a cost efficient way.

Using embedded thin-brick technology on precast's panelized systems can create the traditional masonry look that many school districts seek while providing higher performance benefits that typical masonry can't provide. Precast inset brick panels eliminate months of onsite labor needed for laid-up brick while removing several trades from the site. It ensures a high quality, even appearance and limits the need for on-site inspections. And thin-brick, insulated precast wall systems do not require a wall cavity (like masonry walls), eliminating the potential for future mold and mildew problems.

Precast concrete panels offer variety in color, form and texture. They interface smoothly with glass and

other materials. Precasters' capability to tint concrete and provide numerous surface treatments within one panel creates unlimited design aesthetics. Special mixes and finish techniques are used to mimic limestone, granite and other materials. The finishes are produced more economically than real stone can be purchased and the panels can be erected much quicker. Form liners can replicate textures such as cut stone or slate.

### **Sustainable Design Accomplished**

As educators and stewards of their communities, school administrators want to minimize their projects' environmental impact while providing comfortable and healthy buildings in which to learn and work. Precast concrete systems can help achieve those goals while maintaining a budget that may not allow for "green" building extras.

Precast concrete contributes to sustainable practices by incorporating integrated design, using materials efficiently and reducing construction waste, site disturbance and noise. Using precast concrete can help meet minimum energy requirements, optimize energy performance and increase the life of a building. The constituents of concrete can be recycled materials and precast concrete components can be deconstructed and reused or crushed and materials (aggregate, steel) recycled. Precast concrete and its constituents are usually available locally.

Precast concrete panels offer high durability, which means fewer chemicals are needed to keep it clean and maintained. Insulated sandwich wall panels provide high energy efficiency. And precast's thermal mass helps minimize energy consumption naturally, offering a concrete advantage that drops to the bottom line. This is especially significant for large spaces, such as gyms and pools. Stored thermal energy helps reduce HVAC usage when the school is unoccupied for long periods without risking mold growth. And, precast concrete includes no chemicals that provide off-gassing and thus contributes to a healthier indoor air quality.

Precast concrete systems provide sustainable-design attributes that are recognized by the Leadership in Energy & Environmental Design (LEED) green-building rating program administered by the U.S. Green Building Council. In the LEED rating system, products don't receive points, but appropriate use of precast concrete can help a building earn points in the categories of: Sustainable Sites, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, Innovation in Design, and Regional Priority.<sup>9</sup>

Whether a capital program involves expansion of a single school or construction of multiple campuses, precast concrete provides benefits to contribute to its success. Its ability to be cost-effective, accelerate construction schedules, and achieve aesthetic goals further contribute toward safe, high-performance, sustainable school design. ■

**Peter Finsen**, Assoc. AIA, serves as the chief executive officer of Georgia/C Carolinas PCI, a chapter of the Precast/Prestressed Concrete Institute. He is responsible for association management with key emphasis on educational, technical and marketing promotion of solutions to advance the design, manufacture and use of precast/prestressed concrete products. Peter has a Master of Architecture degree from the University of Pennsylvania and a career that spans more than 30 years in the design and construction industry. With early stints as a design architect, his experience includes PM/CM project development services on over \$6 billion in construction value of educational, correctional, housing, infrastructure and governmental projects. Peter serves on numerous PCI committees, and is active in numerous associations including the American Institute of Architects, American Concrete Institute, Construction Specifications Institute, Design Build Institute of America, and Georgia Society of Association Executives. A long time member of the Council of Educational Facility Planners International, Peter formerly served on the Board of Trustees for the CEFPI Foundation & Charitable Trust.

<sup>9</sup> DN-16-10: *PCI Designer's Notebook: Sustainability*, pp. 10-12.