Prefabrication—Integrating Systems Boosts Efficiency

Designers find integrating materials—masonry, insulation, windows, electrical, plumbing, and more—into precast concrete panels early in the process results in efficiency and economy

— Craig A. Shutt

Designers long have integrated stone veneers and thin bricks into precast concrete panels to gain aesthetic versatility and cost savings. Insulation also has been cast into panels at the plant to provide energy efficiency and construction savings. Now, more materials, including windows, electrical service and HVAC ducts, are being installed in the plant to reduce trades and general conditions, cut construction time, boost quality, and reduce site congestion and liability.

These concepts, while not new, are growing in popularity as designers recognize fabricators' capabilities and the flexibility of precast concrete to create more complete units under factory-controlled conditions while site work continues. This approach also speeds construction and alleviates congestion and coordination of trades.

'Precast concrete was an extremely friendly material to work with.'

An example can be seen at Centralia High School in Centralia, Ill., where designers used embedded thin brick on precast concrete insulated sandwich panels that also included electrical conduit and boxes cast in precise locations. "Precast concrete was an extremely friendly material to work with, "says Steve Scoville, a principal at FGM Architects when the project was designed and now senior project manager at Turner & Townsend Inc. in Nashville, Tenn. "I had assumptions about the limitations of the material's capabilities in meeting our needs. But the opposite was true. It was easy to mold, integrating systems proved to be easy, and we could add extra details, especially around windows, due to the ease of creating accents and the low cost that extended the budget."

Designers for Centralia High School in Centralia, Ill., specified embedded thin brick on precast concrete insulated sandwich panels and also integrated electrical conduit and boxes. Casting in those services at the plant saved considerable time at the site and reduced trade congestion. Photo: Gate Precast Co.

Electrical contractors coordinated their needs with workers at the Gate Precast Co. Ashland City, Tenn., plant to ensure the electrical installation moved smoothly. Photo: Gate Precast Co.

Installing electrical conduit and boxes involves pre-bending the metal or plastic conduit to the desired shape and installing it in the casting bed already connected to the electrical boxes. Photo: Gate Precast Co.

Many Systems Installed

Integrating insulation into the panels can create a continuous thermal barrier which provides the most efficiency. Typically the exterior and interior wythes of concrete can be connected with rigid ties, carbon fiber, longitudinal welded-wire trusses, or solid-concrete connections. However, greater energy efficiency is typically achieved using special, nonconductive ties or carbon fiber essentially eliminating thermal bridging.

Windows and doors also are gaining recognition as systems that can

The panels feature 2 inches of NCFI spray-foam insulation on their back side. Special forms produced sheets of insulation that were cut into strips and used to form dams at blockout locations.

The composite panels erected on the LA Live Marriott hotel had light-gauge steel tubes and galvanized pins added so window crews could install windows at the precaster's plant prior to shipping the panels. In all, 484 pre-insulated, preglazed panels, encompassing 119,000 square feet, were erected. Photo: Clark Pacific.

be integrated seamlessly into precast concrete panels. Door and window frames, properly braced to prevent bowing during concrete placement, can be cast into the panels and then the glazing or door panels are installed prior to or after delivery to the site. Efficiency is gained through the capability of precast concrete molds to create repetition that makes installation move smoothly while providing a secure, protected, open space in which crews can work quickly. Prefabrication eliminates need for site measurements and delays in ordering often long-lead window framing elements.

HVAC requirements are being designed into panels to avoid having to make any penetrations on-site. Return-air vents and other ventilation needs are worked out in advance, with blockouts created in the panels to allow fast installation once the panels are erected. Special attention to waterproofing must be paid and alignment is critical to ensure ideal performance without field adjustments.

Installing electrical conduit and boxes requires coordination with the electrical contractor to ensure everyone's needs are met. The metal or plastic conduit is typically pre-bent to the desired shape and delivered to the casting bed already connected to the electrical boxes. The joints and connections are thoroughly sealed to prevent clogging the system. The wires then are pulled through at the jobsite.

Plumbing units also can be connected and assembled prior to deliver to the site. Bathroom and kitchen modules for residential projects, such as hotels or condominiums, can consist of molded plastic units or be fabricated from drywall components. To eliminate a double floor, the module can be plant-built on the structure member, or the walls of the unit can be designed strongly enough for all fixtures to be wall-hung.

At Centralia, integrating the electrical service required more upfront time reviews of every aspect of the design, Scoville notes. "We had to closely evaluate every shop drawing to work out the details, so there was more time spent in the design stage," he says. "But that was more than offset by the speed of construction. It was phenomenal. It saved a lot of money and got the building enclosed much faster with less scheduling of trades. It was great."

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Electrical contractors worked at Gate Precast Co.'s Ashland City, Tenn., plant to coordinate the installation. The precaster has done other similar projects for school districts, including Garinger High School in Charlotte, N.C., which was produced by the company's Oxford, N.C., plant.

Specifying insulated panels for the high school provided dramatic savings, Scoville adds. "We performed thermal mapping of the school and compared the results with a more traditionally insulated school built at the same time," he explains. "It was amazing how much more efficient and leak-free the insulated concrete panels were."

Preassembled Panels

Some precasters are extending their capabilities beyond traditional insulated, sandwich wall panels to provide additional efficiencies and cost savings. Clark Pacific, for instance, offers a composite architectural precast concrete panel (a thin-shell type of panel). The panels consist of an exterior wythe of concrete, typically 2 ¼ to 3 inches thick, with 2 inches of NCFI spray-foam insulation coating the rear face. Four-inch, light-gauge tube steel is laid over that with galvanized pins to connect the skin to the frame and provide support for window units. The window assemblies are installed with the designer's choice of energy-efficient glazing. HVAC vents, LED lighting connections, and other systems also can be installed.

Performance mock-up tests conducted at Construction Consulting Lab West in Ontario, Calif., showed that the panels meet all ASTM and AAMA tests for air infiltration, structural wind loading requirements, and elastic and inelastic in-plane seismic movement needs.

The panels were used recently to clad the 23-story LA Live Marriott

Composite architectural precast concrete panels with preinstalled insulation and varying sizes of window units clad the 23-story LA Live Marriott hotel in Los Angeles, Calif. Photo: Josh Partee.

hotel, a 295,750-square-foot hotel with 393 units of various sizes. It also features ground-level retail, a rooftop pool, a home theater, and fitness rooms.

"I was unfamiliar with the precast panels until Clark Pacific showed us the concept, but I was interested once I understood them," says Edward Kirk, project manager for Holland Construction, who served at the time as project manager at SODO Builders, the general contractor for the project . "The ability to combine so many systems into one panel in the yard under controlled conditions had a lot of appeal. Installing the systems ahead of time while other work was underway at the site reduced field-installation time greatly, aiding the schedule."

The panels spanned floor to floor with punched window openings of varying widths and spacing. Vertical elements between windows feature returns at either edge that form the window jambs. Gray sill pieces were cast below the window openings, set back 2 inches from the face, while charcoal-colored lintels were set back 3 inches from the face.

Foam Insulation Added

The spray-foam insulation was added at Clark Pacific's Fontana, Calif., plant and represented the first use of the system there, says Marshall Stearns, project manager. "It required special training to get the foam operation up and running." An efficient operation was created to apply 2 inches of NCFI Insulbloc spray insulation to the panels. "By far, the biggest challenge with the insulation was not in the application itself but in keeping it out of areas where it was not required," he says. Forms were built to produce sheets of insulation, which were then cut into strips and used to form dams at blockout locations. At the peak of production, five panels were insulated per day.

Casting window openings and installing the units also created challenges. "One of our biggest challenges was in forming," he says. "Not only were there eight different window sizes, three colors, and two different steps in the panel faces, but the spacing of the windows was constantly changing." Instead of using multiple pans to form the window steps, requiring constant changes and relocations, the precaster cast the recessed sill and lintel pieces separately and assembled then onto the frame. "This allowed production to set up long lines of formwork and cast multiple assembly pieces each day, saving form setup costs and minimizing wasted concrete."

The panels' joints did not receive foam, as the project is located in a high seismic zone. "We didn't want to restrict the panel movements in any way if a seismic event were to occur," says Mike Ryan, director of architectural systems for Clark Pacific. "There was a minimal thermal penalty for not foaming them."

The foam insulation is more costly than typical insulation, he notes, but cost is saved because there's no additional interior stud wall or insulation required. Hat channel and drywall can be applied directly to the back of the panel frame, Ryan says. That also frees up room at the perimeter of the structure.

Another challenge came in preparing the windows for installation. The windows were installed just prior to shipping, but the glazing contractor, Architectural Glass & Aluminum (AGA), still needed to install window clips to ensure quick installation at shipment time.

Three-Step Process Used

A three-day production cycle was established, with the panels cast on the first day. They were stripped and moved to the insulation area for foam application on the second day. They then moved to the sandblasting area, where AGA installed its clips. The panels were then sandblasted and transported to storage.

"Integrating AGA into the production cycle, ensured they could maintain a minimal crew and still keep up with our casting schedule," Stearns explains. When the panels were prepared for shipping, AGA crews installed as many as 36 windows in an eight-hour shift. Installing the windows at the plant ensured the crews worked under controlled conditions with all tools readily available."

For some applications on projects requiring integration of electrical, Clark Pacific has also delivered panels to locations where electrical crews' can perform their work. "By taking the panels to them, we can cut the time requirement for union electricians by half." Says Stearns.

Shipping the panels also took a three-part process. On the first day, the panels were taken from storage, cleaned, and prepared. On the second day, the windows were installed. On the third day, they were shipped to the jobsite and erected. In all, 484 preinsulated, preglazed panels, encompassing 119,000 square feet, were erected.

More than $1.1 million was saved on the façade alone.

The process was efficient and economical, and it will continue to produce savings due to the highly energy efficient design. "Marriott was very risk-averse on this project and wanted no possibility for water penetration or other lapses," Ryan explains. "But their initial design to achieve these goals was way over budget. We showed that by combining the panels, glass, and insulation in a thin, lightweight panel, we could save them more than $1.1 million on the façade. Then we looked at other options to cut costs."

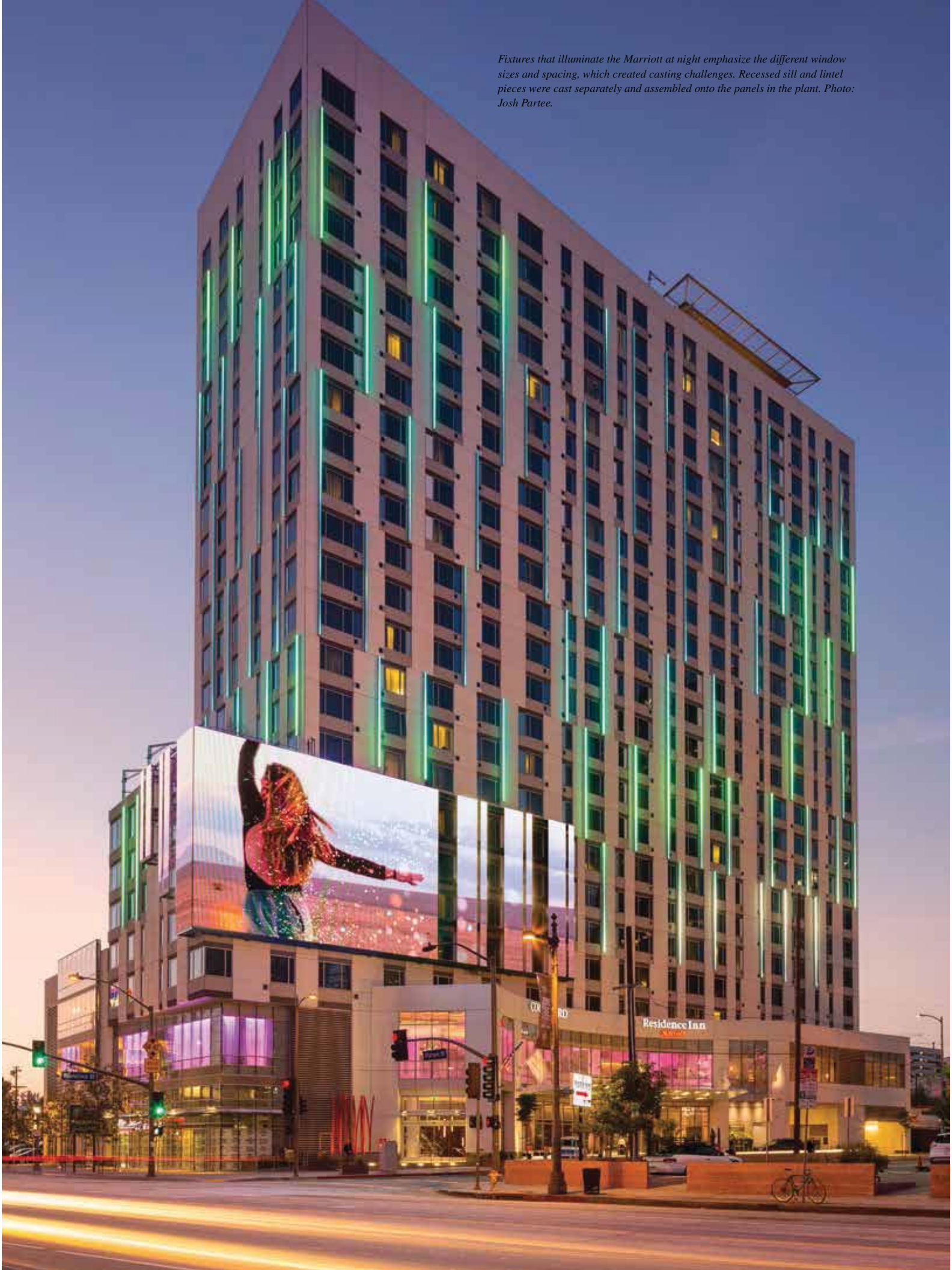
More insulation was considered, he notes, but a cost/benefit analysis showed additional inches resulted in more than a 50-year payback term. "Mock-up testing showed that we'd reached the efficient level, so they cut out some of the redundancies. And the additional jobsite savings in having everything installed ahead of time was huge."

The panels, the largest of which were about 15 by 35 feet, weigh only about 35 pounds per sq. ft., considerably less than a full concrete panel at 65 pounds per sq. ft., Ryan notes. "Over 30 stories of panels, that's a big deal." It resulted in less framing, as well as smaller foundations and lower shipping costs. The weight reductions alone saved about $2 million in construction costs.

The savings throughout the process were considerable, agrees Holland's Kirk. "The system works well if there isn't a lot of articulation required in the skin, due to its thin profile. The panels went on so quickly and so well, there wasn't much pain involved with the installation."

FIU's Integrated System

Across the country, in Miami, Fla., designers on another project saw the same efficiencies by integrating windows into precast concrete panels. The



Fixtures that illuminate the Marriott at night emphasize the different window sizes and spacing, which created casting challenges. Recessed sill and lintel pieces were cast separately and assembled onto the panels in the plant. Photo: Josh Partee.

Precast concrete panels with integrated window units were used on the six-story Science Classroom Complex at Florida International University. The project was done on a design-assist basis, allowing the precaster to work with subcontractors during the design process to integrate as many materials as possible. Photo: Gate Precast Co.

The panels feature integral sunshades in the form of protruding boxes around the window openings, which had angles varying from 0 to 15 degrees.

The glazing contractor installed the windows in the precast concrete panels and caulked them in the precaster's plant, which reduced safety concerns and boosted productivity. It also allowed the windows to be water-tested at the plant and again at the site.

six-story Science Classroom Complex at Florida International University (FIU) serves as a gateway to the Academic Health Sciences Center district within the university's main campus. Materials, scale, and pedestrian connections root the project in its context of student collaboration and high-tech laboratory research.

Precast concrete wall panels with preinstalled windows clad the building. "The project originally came to us with a design-assist approach, so we could work with other subcontractors to integrate project-delivery methods with as many building materials as would work effectively," explains Brian Griffis, regional sales and marketing manager at Gate Precast Co., which fabricated the components.

The companies agreed to have the glazing contractor install the window at the precast facility. "That approach allowed the glazing subcontractor to work on the ground instead of at the jobsite and in the air for most of their scope," Griffis explains. This reduced the liability for the contractor as well as overall schedule.

The precast was designed using 3D BIM software, which aided both construction and prepour quality-control

Organizing Interfaces

Tolerances can be very system-dependent when interfacing precast concrete with other materials, according to the *PCI Design Handbook*. The handbook recommends a seven-step process for organizing the design of interfaces. The design should review:

1. The interface between the two systems, showing shapes and locations, and determine contractual responsibilities (e.g., who provides the embeds for connecting windows and other materials).
2. The functional requirements of each interfacing system and if limits are placed on how the precast concrete units are cast, especially if conflicts with prestressing strand arise.
3. The tolerances of each interfacing system.
4. The operational clearances required.
5. Compatibility of the interface tolerances. Start with the least precise system and compare its requirements against the minimum and maximum dimensions of the interfacing system.
6. Assembly and installation procedures for the interfacing systems to ensure compatibility.
7. The final project specifications as they relate to interfacing. Be aware of subsystem substitutions that might be made during the final bidding.

Key Material Considerations

When integrating systems into precast concrete components, these characteristics should be considered:

Doors and Windows:

1. No gravity-load transfers through window elements.
2. Compatibility with air- and moisture-sealant systems.
3. Open/close characteristics (swing or slide).
4. Compatibility with door-lock mechanisms.

Mechanical Equipment:

1. Duct clearances for complex prefabricated ductwork.
2. Large-diameter prefabricated pipe-clearance requirements.
3. Deflections from forces associated with large-diameter piping and valves.
4. Expansion/contraction allowances for hot/cold piping.
5. Vibration isolation/transfer considerations.
6. Acoustical shielding considerations.
7. Hazardous gas/fluid containment requirements.

Electrical Equipment:

1. Multiple mating conduit runs.
2. Prefabricated cable trays.
3. Embedded conduits and outlet boxes.
4. Corrosion related to DC power.
5. Special insert-placement requirements for isolation.
6. Location requirements for embedded grounding cables.
7. Shielding-clearance requirements for special "clean" electrical lines.

checks to ensure dimensional accuracy. The completed shop drawings were sent to the glazing subcontractor, who built the windows based on the provided dimensions. After production and finishing was complete, a bituminous waterproof coating was applied to the back of the panels. This was done because there are several areas of the project where the back-side of the panels would not be readily accessible once they were installed.

The windows were installed and caulked by the glazing subcontractor at the plant. The panels then were water-tested at the plant and again at the site.

The panels also feature integral sunshades, which created a major design challenge. "The university performed a thorough sun study to maximize shading based on the azimuth of sun traveling across the elevation," explains Pat Bosch, design director and principal at Perkins+Will, the architectural firm on the project. "Precast concrete was the only exterior option that offered the design flexibility to yield so many different shade patterns." This was achieved with protruding sunshade "boxes" around the window openings, which had angles varying from 0 to 15 degrees horizontally and were pitched down.

Tips To Consider

When considering integrating materials into precast concrete panels, architects should consider various factors. "The biggest concern is that designers wait too long in the process to bring in the subcontractors," Ryan says. "The total enclosure and energy system needs to be considered early and as one system, as each part affects others. A full energy strategy needs to be considered. Too often, concepts are mixed and matched and it creates a busy, inefficient wall system." That was the case with the initial Marriott plan, he notes. "It was too complex and busy, adding cost and time that wasn't necessary."

A close communication system, including meetings with the various involved subcontractors, also is critical. This allows each participant to present its most efficient techniques and work to integrate or adapt them to meet others' needs. "Early coordination is definitely a key," says Turner & Townsend's Scoville. "It's critical to work out details upfront." (For more on points to consider, see the sidebar.)

Although more time is spent in upfront communication, planning, and drawing, the work pays off. "The jobsite savings on the Marriott project was huge due to preinstalling so much equipment," says Ryan. The erection was done at night, as the project is directly across from the Staples Center in a congested area. "Preinstalling the windows made the process much faster and easier."

Griffis agrees. "By installing the windows on the FIU project in advance, the glazing subcontractor could focus more time on some of the complex portions of its work at the site without factoring in time for the window installation."

"It's a very effective system," says Kirk. "The ability to combine all systems into one panel in the yard under factory conditions provides multiple benefits. We get high quality, more complete and larger pieces to erect, and a much faster schedule overall."

Adds Scoville, "It was a pretty cutting-edge idea for southern Illinois, but it met all of the district's strict needs for aesthetics, energy efficiency, durability, and scheduling. It was a lot of fun to do that project."