ASCENT CASE STUDY

Precast Design Adds Safety To Residences

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Prototype duplex created at Nebraska University combines precast panels, flooring and roofing to produce an efficient, economical and ultra-safe design

Severe weather across the country, particularly in the Midwest and South, has increased public awareness about the inadequacies of current housing structures. The increasing costs for heating and cooling are also driving developers to find alternative framing sources that can create more energy-efficient housing. A new precast concrete design created by a group of designers headquartered at the University of Nebraska-Lincoln offers great potential to aid in that search.

The program, which produced a two-unit townhouse, was coordinated by Maher Tadros, the Charles Vranek Distinguished Professor in the school's civil engineering department. He worked in conjunction with university officials and Omaha-based Enterprise Precast Concrete Inc. and general contractor TFF Inc. "Our goal was to prove that a precast concrete envelope could be superior to wood framing," he says. "We wanted to show that a concrete design not only offered added strength but many other advantages as well. And by all measures, it was a complete success."

This duplex in Omaha, Neb., features precast concrete wall panels, flooring and roof beams, producing a sturdier home that's pleasing to the eye.

Three Precast Elements Dominate

The design focused on three new precast concrete design elements: a patented design for an insulated sandwich wall panel, a floor-joist panel and a roof beam that could be expanded into the entire roof structure. Using these three together, Tadros says, creates a design that offers great potential for virtually all regions of the country. To prove this, the group created a duplex in Omaha to serve as a demonstration house. "We wanted to show the public how the components would work, to generate interest and to prove the system works," he says. The concept worked so well that both units have been sold to homeowners, who are now living in the units.

The homes' wall panels are fully composite and fully insulated. The concrete wythes are connected through the insulation layer using fiber-reinforced plastic bars formed into a unique shape. The bars were bent into a C shape to form the diagonals of a truss along the height of the panel. Lines of connectors were placed at 2-foot intervals within the panel to transfer the shear force from one side to the other. In each concrete wythe, a specially fabricated D10 x D10 at 3 x 3-inch welded-wire reinforcement sheet was placed midway through the thickness. The large deformed wire (about 3/8-inch in diameter), spaced at the small 3-inch spacing, was the only reinforcement required.

"In addition to the high strength and high precision of placement of the reinforcement sheet, its relatively narrow spacing helps distribute forces to control cracking," Tadros says. "With this reinforcement, no individual reinforcing bars are required, and the walls can resist full soil pressure as a basement foundation wall. It also can resist hurricane-level wind forces as an above-grade wall with no additional reinforcement."

The panels proved to be the most challenging part of the project from

Fact Sheet

Project Name: University of Nebraska House
Type: Duplex housing
Location: Omaha, Neb.
Owner: Private homeowners
Designer: Kenneth Hahn Architects, Omaha, Neb.
Engineer: Maher Tadros, University of Nebraska, Lincoln, Neb.
Contractor: TFF Inc.
Precaster: Enterprise Precast Concrete, Omaha, Neb.
Precast components: 60 pieces of precast concrete, including wall panels, beams and hollowcore
Project cost: $490,000

the precaster's perspective, says Bill Wilkinson, project manager at Enterprise. "When we first saw the design, we realized that shipping the panels could be a huge issue." The plans called for 60-foot-long pieces that would have been difficult to transport due to local regulations, and hard to handle in the yard and at the site.

"We had to redesign some of the panels to create better casting efficiencies," he says. "But that became mostly a number-crunch to ensure we could ship them and didn't exceed the crane capacity for weight. But even at the new sizes, handling the panels in and out of the forms and into the yard was a challenge due to their bulkiness." The panels typically were cast about 40 feet long, with the largest pieces measuring 45 feet long, 11 feet high and 10 inches thick.

The truss system also had a learning curve, Wilkinson notes. The fiberglass pins required a new setting system that was unfamiliar to the casters when they began. But they quickly adapted. "The process went relatively smoothly, and we were able to cast the panels pretty quickly for insulated pieces. Their size was the biggest concern."

'The precast panels can resist hurricane-level wind forces as an above-grade wall with no additional reinforcement.'

Floor Uses 'Stems'

The main components of the precast concrete floor system are the longitudinal stems, which measure 3 inches wide and 15'5" deep. At least two, and at most five, longitudinal stems were connected together with cross ribs to form a panel. The longitudinal panels were spaced 2 feet apart, creating a two-stem panel that was 2'3" wide. With prestressing, the panel was capable of spanning up to 40 feet without any intermediate supports in the basement.

"This ability to offer clear spans is an advantage for the designer, providing flexibility in designing and finishing the basement to the homeowner's satisfaction," Tadros says. "It created total interior design flexibility." Cross ribs allowed panels to be installed without bracing or bridging, he notes. Enhancing the system's flexibility were 8-inch-diameter holes cut into the middle zone of the stems to allow installation of utility ducts within the floor depth. The concrete floor was covered with an oriented strand board (OSB) wood substrate, while the underside was finished with gypsum wall board to create a ceiling.

The advantage of this system is that the floor panels can be positioned adjacent to each other or spaced as much as 2 feet apart, Tadros says. "Designers can select the length and width of the panel,

as well as panel-to-panel spacing to suit the desired floor dimensions." A key advantage is that there is no vibration or squeaking, which can occur with wooden floor joists. The weight of the system compares to a typical solid-concrete slab of about 2½ inches, making it much lighter than any other concrete floor system available, he notes. The longitudinal stem's vertical dimensions allow for masonry-wall coursing if the designer wants to combine these materials, he adds. The center-to-center spacing of longitudinal stems allows for standard (4- by 8-foot) OSB sheets with little waste.

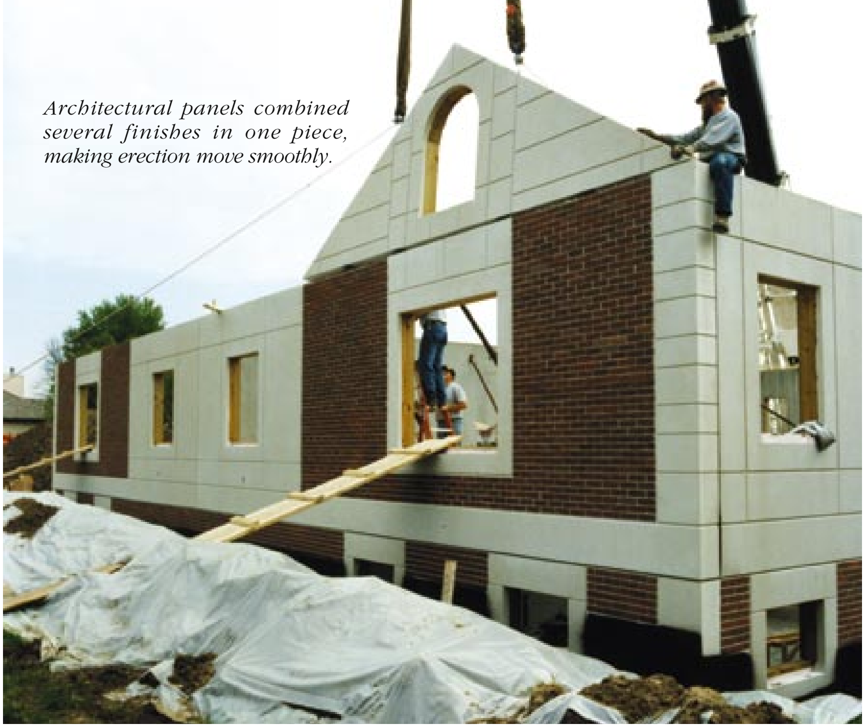
'The ability to offer clear spans creates flexibility in designing and finishing the basement.'

Roofing Concept Adjusted

The precast concrete roof-beam concept remains only a concept, due to changes to the plan, Tadros explains. "Early in the project planning, it was determined that a total-precast concrete roof system would not be economical because the roof's appearance had to match other buildings in the neighborhood." That meant it had to have a roof pitch of 3:4 and include several dormers as well as a number of ridges and valleys with complex geometry. As a result, wood framing was used.

"I wish I had held out and used the precast concrete roof, as I know it would have worked, and it definitely would have provided more protection to the homeowners," says Tadros. As it was, the final design features a 35-foot precast concrete roof beam, with the beams anchored to the walls and the wood trusses anchored

Precast concrete flooring consists of longitudinal panels spaced 2 feet apart, which provided spans up to 40 feet in the basement.



Architectural panels combined several finishes in one piece, making erection move smoothly.

to the beams. This created a system that resists wind uplifts during high winds and tornadoes. The beams also act as platforms to support the trusses at much shorter spans than the spans between exterior walls. It also provided space in the attic for a tall loft area measuring about 600 square feet.

Several steel and concrete options were considered for the roof beams, he adds. These included an I-shaped conventionally reinforced concrete beam, an I-shaped steel beam and partially prestressed concrete hollowcore plank. The hollowcore option was comparable in cost to the steel-beam option. It was selected to use as much precast concrete in the design as possible. The hollowcore planks, measuring 12 inches thick by 24 inches wide, were produced by Concrete Industries Inc. in Lincoln, Neb. "They were wet-cast pieces that caused no significant problems to produce. Some ends were mitered to clear the roof truss, and they were equipped with bearing plates to provide positive bracing of the walls and resistance to uplift," explains Mark Lafferty, vice president.

"The precast concrete roof is as viable as a wood roof and much more protective," says Tadros. "It might be more expensive to produce in its initial cost, but the long-term benefits are tremendous." These include marketing benefits to the builder, who can promote the added wind protection and safety measures.

Tadros' interest in communicating the viability of concrete roof framing, he adds, led him to assign a semester-long class project to his senior-level concrete-design class. "At the beginning of the project, many of the students thought their instructor needed brain surgery," he says. "By the end of the semester, the students were the big promoters of concrete roof framing for residential construction."

Construction Moves Quickly

A 150-ton mobile crane placed the precast concrete panels onto cast-in-place footings or onto short, cast-in-place round piers near the garage and walkout areas, where footings had to be placed below the frost line. The basement wall and floor panels were

'The precast concrete roof is as viable as a wood roof and much more protective.'

assembled in only three days, with all of the precast components, including the second story and roof, installed in five days total.

The panel-to-panel connections, which consisted of standard hardware, were designed for speed of erection, high tolerance levels at the site, high strength and durability. The main connection device was a structural-steel tube with oversized holes. When two panels were erected next to each other, the tubes from the adjacent panels were bolted through the oversized holes.

"The speed of construction provides a significant advantage for this housing design," says Wilkinson. "To be able to erect the exterior in several weeks or less and begin working on the framing and other interior trades can create a strong advantage. It's unheard of for conventional construction. The advantages work not only to continue construction through a Midwest winter but also in Florida's rainy season. Putting up a shell in two days can be very attractive."

Panel-to-panel connections were designed to speed erection, which provided a significant advantage over typical construction.

Precast's ability to provide an aesthetically pleasing look while offering other advantages gives it great potential for future housing projects.

Tadros names other significant benefits that the design provides. These include:

- **Durability.** "Precast concrete provides long-term durability and requires little or no maintenance," he says. Termite infestation or dry rot can cause severe damage to wood-framed homes, he notes, but they don't affect concrete homes. The dense panels also help reduce sound transmission into the home, making it quieter.
- **Safety.** "Resistance to fire and natural disasters, such as tornadoes, earthquakes and flooding, are significant benefits of a concrete house."
- **Aesthetics.** "Unlimited architectural treatments are possible with precast concrete," he says. In addition to a wide range of surface textures and colors, permanent brick and textured exterior appearances can be created, matching any style desired for an existing or new neighborhood.
- **Environmental impact.** "Precast concrete is an environmentally friendly material," says Tadros. "The thermal mass of concrete and the high insulation efficiency of the system save energy and reduce daily and seasonal temperature swings."
- **Design flexibility.** The long spans allow the exterior wall panels to serve as the only load-bearing elements, keeping the interior space column free. "Having no interior load-bearing partitions allows total flexibility of room layout and future remodeling." With a precast structure, he suggests, it's possible to have a 10-foot or higher ceiling at virtually no additional cost while providing a feeling of openness and spaciousness in the home. For roofs with a steep slope, the flat roof beams create an attic space that can be converted into loft space with reasonably high headroom. "This option is difficult to provide with traditional wood-truss roof systems."
- **Lower long-term costs.** "Because the precast exterior requires little maintenance, and operating costs are much lower than with a conventional wood house, the building retains its high value long after the mortgage is repaid," he says.

Tadros and his team are currently refining the panel's design and testing further concepts to enhance efficiency. "We've already solved the great majority of technical issues that are involved, the design only requires fine-tuning," he says. "Then it will be a matter of marketing and psychological issues."

The latter may be the most formidable. "Precasters and architects are unfamiliar with the concept, and especially in a busy economy, when they have other work to produce, they want to use familiar designs."

Marketing the advantages will help interest designers, because owners and homeowners will be intrigued by the

'Precast concrete is an environmentally friendly material.'

benefits, says Colm Breathnach, sales and marketing manager at Enterprise. "There are a lot of advantages with a precast system that aren't apparent from talking about its structural frame," he says. "To really take off, we have to focus on other key properties, such as the fire and wind resistance, sound control and life-cycle costs. Its ability to last 150 years rather than maybe 80 for a wood-frame house also offers benefits to homeowners."

The perception that concrete homes are difficult to remodel or adapt — or even that it's hard to hang pictures — will need to change, and that will take a significant effort, he says. "But it will come with time, as more people become aware of the design and its potential. There are many markets where a row or terrace house made with precast concrete could be created quickly and very, very efficiently. I think it's only a matter of time before it becomes a popular option." ■

— Craig A. Shutt

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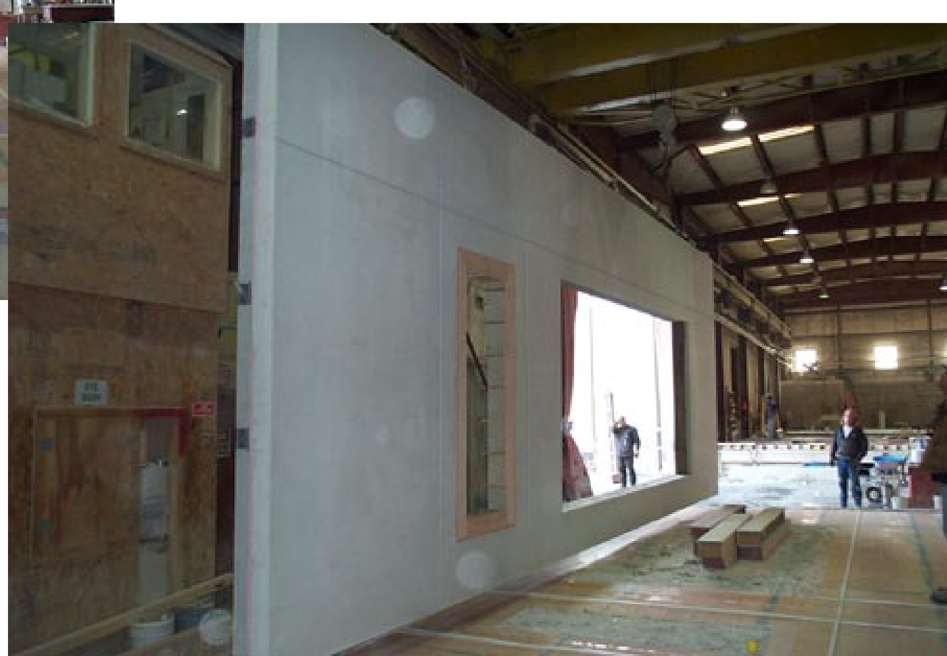


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