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University project pushes precast challenges to the limit

For about a decade, the architecture students of Doug Noble and Karen Kensek at the University of Southern California (USC) in Los Angeles have been developing design ideas for hypothetical precast concrete projects to be located in Joshua Tree National Park, about 125 mi (200 km) east of USC.

"We did designs for visitor centers and education facilities," says Noble, who is the associate dean for academic affairs in the School of Architecture at the university. "Then, in 2018, we decided to change our strategy and do a real project." The team needed something small that they could do themselves and something that the National Park Service would accept. Eventually, they opted to create a prototype replacement for the standard vault-toilet restroom buildings that are found in parks nationwide. "It is almost the only type of built work inside Joshua Tree National Park," he says. "They only have roads, signs, trash cans, and toilet buildings."

The team opted to call the structure the Carapace Pavilion and began working on it that summer. A carapace is a protective covering, like the hard upper shell of a turtle. A grant from the PCI Foundation helped pay for the supplies and materials.

University of Southern California students used a complicated mold design for the Carapace Pavilion, the centerpiece for a new VIP campground for Joshua Tree National Park in southeastern California. A PCI Foundation Grant helped pay for the project.

University of Southern California architecture student Rachel Hamilton applies a skim coat to the precast concrete around the openings in the panels of the Carapace Pavilion. All photos courtesy of Douglas Noble.

The design proved to be a challenge. "We knew we wanted to make a prefabricated precast building that could be set in place in one day," Noble says. "We also knew we would only get one mold, so we had to create a design that could be assembled from pieces that would be cast into that one mold."

The team also chose, on purpose, to make the project as difficult as possible. "As a university, we are motivated to push the frontiers of what is possible, even in a regular design studio for undergraduates," Noble says. In fact, this project became so complex that the team could no longer sketch it by hand or model it in three dimensions with traditional software. As a result, they partnered with a graduate student who created a software scripting tool that the team used for the mold and project design. The students refined and reworked the original ideas using the software tool creating many new features for the project.

The Carapace Pavilion waits, prior ot cleaning, in the Clark Pacific casting yard in Fontana, Calif., to be installed at Joshua Tree National Park. The structure is 42 ft (13 m) long overall and 13 ft (4 m) tall. The steel fiber reinforcement in the ultra-high-performance concrete will rust and streak over time, helping the structure's colors blend into the natural environment.

"I have worked on real and hypothetical projects of all sizes, but this tiny little pavilion was the most challenging project I have ever worked on," Noble says.

The structure was designed to be curved in two directions. "We placed almost 200 openings in the panels, and each opening was different. We had to fabricate the mold ourselves."

The team opted for ultra-high-performance concrete (UHPC), which none of them had ever used before. One reason for choosing UHPC was that the structure will be placed in a high seismic zone. "Fortunately, we had great advisers from PCI and from Clark Pacific, who watched over us carefully," Noble says.

Construction also posed challenges. For example, although making the foam mold was fairly easy, assembling the mold pieces was difficult. "As novices, we did not understand construction tolerances and digitally fabricated everything exactly the right size to two decimal places," Noble says. "However, when the pieces got warm in the sun, they did not fit." The team dealt with this by shading the work area, working in the cooler morning hours, shaving some of the foam by sanding the sides of the individual pieces, and leaving a small gap around some of the panels, which made the whole project about half an inch wider overall.

Reinforcement was also a critical concern. Because the team had opted for UHPC, they chose not to use the standard reinforcing bars, which are common in traditional precast concrete. "UHPC uses discontinuous glass or steel fibers," Noble says. "We opted for steel, and these steel fibers are small, less than an inch long and super thin. They are like needles."

The team made this decision because it wanted to make a project that looked like it belonged among the ancient rock formations of the desert landscape in the park. The steel fiber reinforcement plays into the look. "We wanted it to be rough and stained on the outside to look like the rocks," he says. "The steel fibers will rust and streak and look great. We did an accelerated aging test sample, and it is absolutely perfect."

The structure was engineered under the assumption that the UHPC would attain 17,000 psi (117 MPa) compressive strength. To everyone's delight, the seven-day strength was more than 25,000 psi (172 MPa). "I could not have asked for a better material match for the project," Noble says, "and concrete is the only material we used. It is a precast building on the outside, on the inside, and all the way through."

Although the inside of the structure is silky smooth, its rough outside mimics the rocky landscape. "We also did calibrated color matching to the local site and selected a shade of pink that will match the sunset colors of this desert environment," he says.

When the structure is finally installed—which is expected to be sometime between December 15, 2021, and March 15, 2022—the team will partially bury the pavilion, which is roughly a tube. The team designed a special raised bed of local earth and then scraped out the double-curved geometry so that the pavilion would sit down low into the ground. Eight giant screws known as earth anchors will secure the pavilion once it is in place, and the inside of the tube base will be filled with local earth.

While the pavilion rests in a precasting yard awaiting schedule alignment, the team carefully planned a route to accommodate the structure as it is transported to the site on a double-drop trailer. "The last mile or so is a dirt road, so we will also have to monitor rainfall to avoid going in and getting stuck in the mud," Noble says. "Fortunately, it is a desert and rainfall is rare."

Even prior to the Carapace Pavilion's installation in Joshua Tree National Park, the industry is taking notice. In October 2021, it received a Citation Award for Installations from the Los Angeles chapter of the American Institute of Architects.
—William Atkinson