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Sphere of Influence

Architects employ precast concrete for Miami museum's dome planetarium and building façade to make a bold design statement.

By Shari Held

Photo courtesy of Grimshaw Architects


PHILLIP FROST MUSEUM OF SCIENCE

Each of the dome's precast panels consists of 5,000-psi, post-tensioned concrete.

From the very beginning, it was destined to be a one-of-a-kind, world class project. Miami's ambitious $300 million Patricia and Philip Frost Museum of Science epitomizes quality and an exacting level of complexity – from its 500,000-gallon, martini-glass shaped seawater tank to its full dome 3-D planetarium and striking geometrical-patterned façade.

It's no wonder the 250,000-square-foot museum, slated to open in summer 2016, is garnering international attention.

The main objective of the museum board was to make the structure's architecture part of the exhibition.

"The way in which the systems are developed and the façade is engineered is all part of their mission to make the invisible, visible," said Aaron Vaden-Youmans, senior architect for Grimshaw Architects.

They also wanted the planetarium to express its function, resulting in its spherical shape. Stark white precast concrete was used for both the planetarium's dome and the Bar Building's geometrical-patterned façade, which was inspired by simple shapes found in nature. The precast components allow the museum to achieve a stunning visual appeal.

AN OPTIMAL SOLUTION

Precast wasn't the first choice for the planetarium dome. The bottom half of the sphere is cast-in-place concrete and designers originally considered a total cast-in-place planetarium as well as a steel-frame dome.

However, serious concerns about the finish quality on the upper half of a cast-in-place sphere led Grimshaw to abandon that option. And the thickness of the cladding needed to acoustically seal a steel-framed dome was nearly equal to the cost of a precast dome. There would also be the added cost of the steel frame.

Grimshaw awarded the contract to Gate Precast Concrete for the precast planetarium dome and decorative exterior wall panels. There were many reasons why precast was the perfect solution for the dome.

"Precast is precise, is made in a controlled environment, can be very high strength and can have an outstanding architectural surface that doesn't require additional finishing and painting," said Dr. Maher Tadros, professor of civil engineering at the University of Nebraska. Tadros is working for Gate as a consultant on the project. "It's also fire-resistant, hurricane-resistant and tornado-resistant. But it requires very intense engineering and planning," he said.

Photo courtesy of Gate Precast

Precast domes are quite rare for that reason – especially when they boast an 87-foot-diameter outer shell.

"To our knowledge, our dome is the only one that has ever gone to the equator portion of a sphere," said Bryant Luke, vice president of operations for Gate.

The 32 precast pieces that make up the dome, dubbed "orange peels," are **58 feet long** and **weigh approximately 60,000 pounds** each.

PLANNING AND PRODUCTION

"The big challenge on the dome was to make it self-supporting," Luke said. "To give it an architectural look while it was actually a structural component."

MIDAS engineering software and Revit drafting software assisted with the engineering.

The 32 precast pieces that make up the dome, dubbed "orange peels," are 58 feet long and weigh approximately 60,000 pounds each. To achieve a sphere shape once the dome was erected, each peel features a length-wide radius plus a curve in the width of the panel. The base of each peel is 10 feet, tapering to 2 feet at the top.

Each of the panels are conventionally reinforced, consisting of 5,000-psi, post-tensioned concrete.

SAFETY FIRST

Until all of the peels were in place, the dome couldn't be self-supporting, so Gate designed and installed a shoring tower to support the dome while under construction.

"From a safety perspective, the engineering of the shoring tower was critical," said Andy Allen, project director for Skanska, the general contractor on the project. "We had to be absolutely certain that the pieces stayed where they were placed."

Skanska supplied an on-site superintendent whose sole responsibility was to manage that process. The company also placed additional safety engineers on site during the entire operation. The shoring tower was inspected daily to ensure its integrity since it also served as a work platform for erectors and welders.

The precast façade on the museum's Bar Building boasts a variety of subtle variations to create a unique design aesthetic.

Photo courtesy of Gate Precast

The daily pre-task planning was elaborate.

"Any time there was the slightest thing that would cause us to deviate from that plan, everybody would stop to re-discuss and re-plan what needed to be done next," Allen said.

LOGISTICS AND INSTALLATION

To safely transport the peels from Gate's Kissimmee, Fla., manufacturing facility to Miami, Gate fabricated six specialty frames to securely hold the peels on a flatbed truck. The peels were delivered to a staging area a few blocks from the site, then transported to the site individually as needed.

Space on the job site was limited. A public road to the art museum covered 50% of the access and the Bar Building covered the other 50%. And the bottom half of the planetarium was already in place.

That meant the 550-ton superlift crane had to remain stationary throughout the installation as it hoisted each peel more than 80 feet in the air to assume its place. The challenge at this point was to find the optimal position for the crane and for peel delivery with minimal disruption to the roadway.

"Once we got the plan in place, it was simply a matter of implementing it," Allen said.

First to be placed were the two pieces that compose the approximately 30-foot-diameter cap of the dome. These pieces were temporarily welded to the shoring tower. Then came the meticulous task of attaching each individual peel to the capstone, moving clockwise and alternating one peel with its opposite to achieve counterbalance.

To speed the process, the peels were installed during the day and welded into position at night.

"Getting that flow down right was critical to getting everything assembled correctly," Allen said.

FABULOUS FAÇADE

The dome may have been the most challenging precast structure on the project, but the decorative façade on the north, west and south sides of the Bar Building brought its own set of challenges. It's the first thing people see, whether approaching the museum from the causeway or via air en route to Miami International Airport, so it had to be visually appealing.

But the complexity of the systems within the museum meant less money could be allocated for it. "The original concept was a modular façade that could achieve an economy of aesthetic by repeating but subtly changing," Vaden-Youmans said.

Grimshaw first considered using large terra cotta forms, then glass-fiber reinforced concrete. But precast prevailed.

"It became clear over the process of designing and value engineering that precast was both affordable and could create a visually complex and compelling façade," Vaden-Youmans said, adding that precast is self-finishing, eliminating the need for a rain screen.

A DOSE OF INGENUITY

The challenge Gate faced was how to make the project "production friendly." Grimshaw's original plan called for many variations of molds to produce the wall panels. The patterns on the panels needed to be random, but there were restrictions on where repeats could occur. And since the panels were going to serve as the backdrop for the museum's light show, the joints and reliefs needed to create appropriate shadows.

Photo courtesy of Gate Precast

Achieving the finished look took a generous dose of ingenuity.

"We couldn't do the entire exterior in 4-foot-by-4-foot sections," Luke said. "Nor could we make a custom-built mold for every single panel. One would have taken too long and the other would have been too expensive."

In the end, Gate accomplished the look and made it practical to produce by using 16 4-foot-square shapes.

The façade consists of 10 1/2-inch-thick modular precast panels each weighing about 25 tons and ranging in size from 8-to-12 feet wide to 30-to-48 feet tall. Nearly every panel is unique and is comprised of a combination of 4-foot-square sections, each featuring a different geometrical design element. The middle of each section is either concave, convex or flat to provide further variation.

Photo courtesy of Grimshaw Architects

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– Aaron Vaden-Youmans, *senior architect, Grimshaw Architects*

Gate used computer numerical control milling to create the forms for the panels.

"We figured out a way to modify those 4-foot-square sections inside the mold to get five or six different variants from just one mold," Luke said. "It was a very complicated process."

Thanks to extensive planning and rehearsal, the installation of the panels was straightforward, although there was limited space and tight constraints.

"Gate did a great job with their quality control efforts to make sure they got a very uniform and consistent appearance in the precast concrete," Allen said.

The result is stunning.

"The way the shadows play on the subtle concave and convex modules achieves a strong aesthetic form that's beautiful, but also subtle," Vaden-Youmans said.

TOP MARKS

All of the project players are ready to take on another precast dome now that they've got the experience.

Vaden-Youmans, who hadn't worked extensively with precast prior to this project, was impressed with precast's capabilities and the fact that there were so few hiccups along the way.

"I would certainly seek to use it again based on this experience," he said.

If Vaden-Youmans has one word of advice for precasters, it's to get out and give presentations to architectural firms.

"A lot of what they are doing and are capable of doing is not well-known in the profession," he said.

And those capabilities change daily.

"Precast has existed for 60 years or so, but in reality it's still a baby being formed," Tadros said. "With precast concrete, the sky's the limit." PS

Shari Held is an Indianapolis, Ind.-based freelance writer who has covered the construction industry for more than 10 years.