Fig. 1: Located directly across from Museum Park, Miami, FL, and overlooking Biscayne Bay, One Thousand Museum is the brainchild of the late Zaha Hadid
(rendering courtesy of Zaha Hadid Architects)

Dubai Producer Shapes a New Miami Icon

Form(work) meets function in the One Thousand Museum building

by Deborah R. Huso

While Dubai has recently become famous for its curving and twisting towers, Miami has long been known for its art deco historic district and its coast-hugging high-rises. Thanks to a talented design and construction team, the Florida city now has a dramatic new landmark. More than 80 residents will soon occupy the tower—one that's likely to become one of Miami's most coveted addresses.

Located directly across the street from Museum Park and overlooking Biscayne Bay, the 62-story, 709 ft (216 m) tall One Thousand Museum building is supported by an architectural concrete exoskeleton. The exotic and organic structure (Fig. 1) is the brainchild of the late Zaha Hadid, an Iraqi-born British architect and the first woman to receive the Pritzker Architecture Prize. Fittingly, the design and construction of the building are the products of a range of partnerships stretching halfway across the world, from Miami to Dubai.

The undulating form of the tower was created using cast-in-place construction. While traditional removable wood formwork was used to construct the lower floors, stay-in-place glass fiber-reinforced concrete (GFRC) forms were used to construct the exposed structure above the 14th floor (Fig. 2). The GFRC also serves as the cladding, creating an eye-catching, sinuous exoskeleton on all four elevations.

Choosing a New Form of High-Rise Construction

The inspiration for One Thousand Museum ultimately came from the shared desire of co-developers Louis Birdman and Gregg Covin to fill what Chris Lepine, Associate Director at London-based Zaha Hadid Architects, calls "the Biscayne wall" of high-rise residential buildings on Biscayne Boulevard. "They didn't want to repeat the condo towers already on the market," Lepine explains. Other developers on the project included Gilberto Bomeny and Kevin Venger.

Given the tower's proposed location across from Museum Park, Zaha Hadid Architects wanted to create something of a residential sculpture. "Our office has an interest in fusing architecture and structure," Lepine says. "We were looking at how to make a structure authentic but also beautiful."

Zaha Hadid Architects had designed an earlier building with an elaborate façade in Cairo, Egypt, using GFRC panels, but its construction fell through with the onset of the Arab Spring. "A year later, this Miami project came up," notes

Fig. 2: While traditional removable wood formwork was used to construct the columns and brackets for the lower floors, stay-in-place GFRC formwork units were used to construct the columns and brackets above the 14th floor. Elevated slabs were cast on conventional flying tables *(photo courtesy of ODP Architects)*

Lepine. His team immediately thought about using GFRC.

Kurt Dannwolf, President of O'Donnell Dannwolf & Partners Architects (ODP) in Hollywood, FL, who served as architect of record on the project and partnered with Hadid's office, says One Thousand Museum "is the tallest use of this process by a long shot in the world."

But it was not a given that the design-build team would use GFRC forms. Contractors had limited experience with the product, and there were only two approved producers in the world. To limit risks, the developers requested that Zaha Hadid Architects and ODP explore additional options.

Both conventional cast-in-place construction and cast-in-place construction with permanent formwork went through the design development phase, according to Luis Ramirez, New York City-based Principal at DeSimone Consulting Engineers and Project Director for One Thousand Museum. But conventional cast-in-place construction would have slowed construction to the point that the project would not have been feasible.

However, the design-build team did employ conventional cast-in-place concrete construction to create the structural members of the building's lower floors. The concrete elements of the first 14 floors were very large—some up to 30 ft (9 m) in length and 6 ft (2 m) thick—too large to use GFRC as formwork. On the lower floors, GFRC therefore serves only as cladding installed after the conventional formwork was stripped.

The design did not require such massive dimensions on the higher floors, however, so the team used prismatic "extrusions" to support those levels. From level 15 up, GFRC serves as a construction, structural, and architectural component. Harald Halvorsen, Director and Partner with GFRC producer Arabian Profile Company Limited (APCL) north of Dubai, says the GFRC saved on "the cost associated with erecting and dismantling formwork [and] rendering and painting of the concrete surface, thereby giving a substantial cost savings to the developer as well as [saving] several months' construction time."

Building and Installing the Formwork

As the GFRC manufacturer, APCL provided about 3250 formwork components to the project, ranging in size from 15 x 8 ft (4.6 x 2.4 m) down to 4 x 8 ft (1.2 x 2.4 m). The company employed 960 molds in the production of the GFRC forms and architectural cladding. Using 220 additional molds, they also produced about 350 glass fiber-reinforced polyester panels used for the gill-like cladding of the garage floors (level 2 to 7).

While each floor of the tower incorporated a variety of form sizes, APCL was able, in principle, to use a mold twice. "The biggest challenge was achieving a smooth interface between GFRC elements and the adjacent floors," says Halvorsen. "We had to work within a tolerance of 1 mm [0.04 in.]." Using a CNC router, APCL achieved high-precision mold work. They also practiced assembling adjacent floor elements for fit in the factory prior to packing and shipping. Even so, not all the panels worked perfectly on arrival at the jobsite. "They didn't always go together like a Lego set," Dannwolf explains, so there was some "hacking and patching" on-site.

One Thousand Museum pushes the limits of concrete construction with its use of GFRC panels clamped together to confine cast-in-place concrete (Fig. 3). "It's the first building in the world of this scale to use GFRC as permanent formwork, completely integrated with the structure," Lepine says, noting the tallest such structures in the past have been no more than two to three stories.

The GFRC forms were designed to be assembled on-site. "The original idea was to create the rebar cage and then come

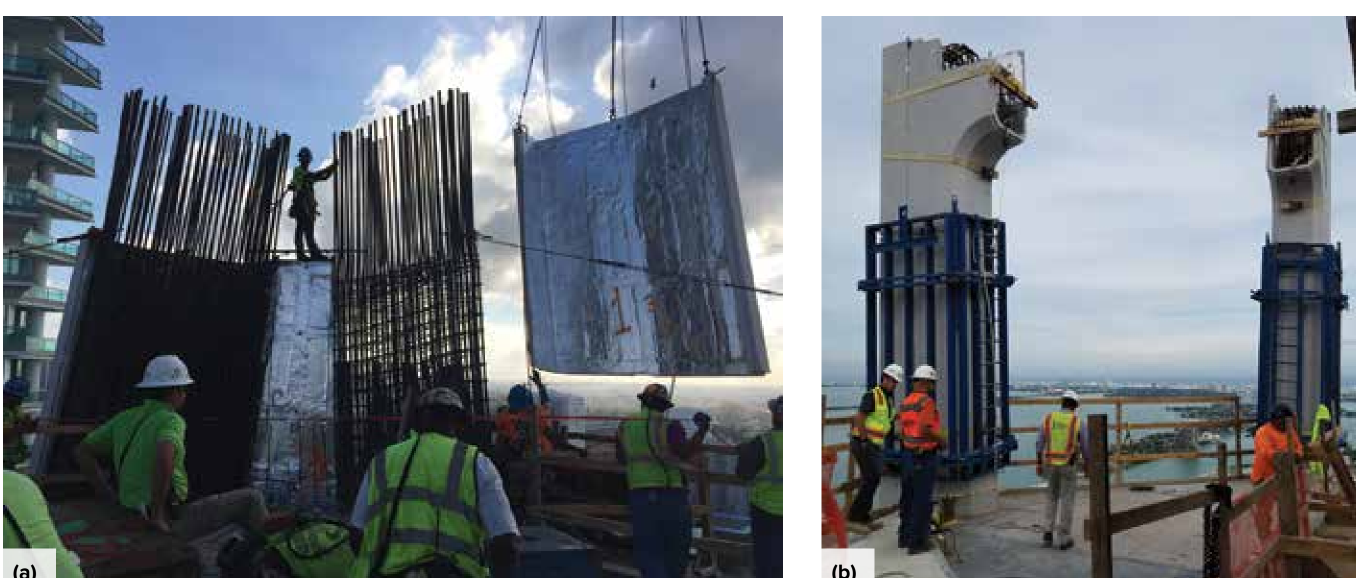


Fig. 3: GFRC forms were assembled around the reinforcing bar cages and clamped together: (a) the exterior forms included a vapor retarder *(photo courtesy of Plaza Construction)***; and (b) steel frames and nylon straps were used to confine cast-in-place concrete** *(photo courtesy of ODP Architects)*

Fig. 4: Column-free floor plates were created using post-tensioned, 11 in. (280 mm) thick slabs *(photo courtesy of Plaza Construction)*

in with two halves, put them together, and then strap them," says Ramirez. "That was the original mockup, but the collective on the construction side decided to come up with a steel frame that would tie the two together, which was more efficient for repeating everything over and over again."

Architectural Features Become Structure

The building program called for expansive condominium units featuring five bedrooms and minimal wall partitions. Thus, the designers' challenge was "to maximize freedom of layout with almost no internal structure," explains Lepine. Yet, the building had to be designed to resist the wind loads expected in the hurricane-prone location.

The floor plate is based on a square with an exoskeleton wrapping around it. This offered the opportunity to make all four sides identical, allowing multiple uses of molds for the GFRC units. "We got as much repetition as we could while still keeping it unique," Lepine notes. From level 25 to 48, there are six different shapes repeated on every single floor. Above that, there is just one shape repeated on all four sides.

A big part of what gives the exoskeleton its strength and allows for a thinner core is the diagonal bracing it provides. "What you see today on the exoskeleton is different from what Zaha originally conceived," says Ramirez. "There was initially a gap at the center of the 'X' on the building. We saw the opportunity to connect the two and create it into a true braced frame." This allowed the exoskeleton at the periphery of the structure to take more of the wind load, reducing the demand on the central core and reducing wall thicknesses and the vertical extent of the central core.

The perimeter structure results in floor plates that are virtually free of columns, allowing for varied and individualistic floor plans for every unit. The resulting spans of 30 to 50 ft (9 to 15 m) necessitated post-tensioned, 11 in. (280 mm) thick slabs (Fig. 4), rather than the more typical 8 in. (200 mm) slabs required in a conventional structural scheme.

The floor plates from level 10 to 32 also include large balconies with areas of up to 1000 ft^2 (93 m^2). From the centerline of the column to the end of the balcony the cantilever is as much as 30 ft (9 m). While the brackets coming off the columns were not initially part of the structure, the design team decided to use them as structural elements to reduce the span of the slab cantilever (Fig. 5). According to Ramirez, "Everything that you see from level 10 and above is structure with the exception of the windows."

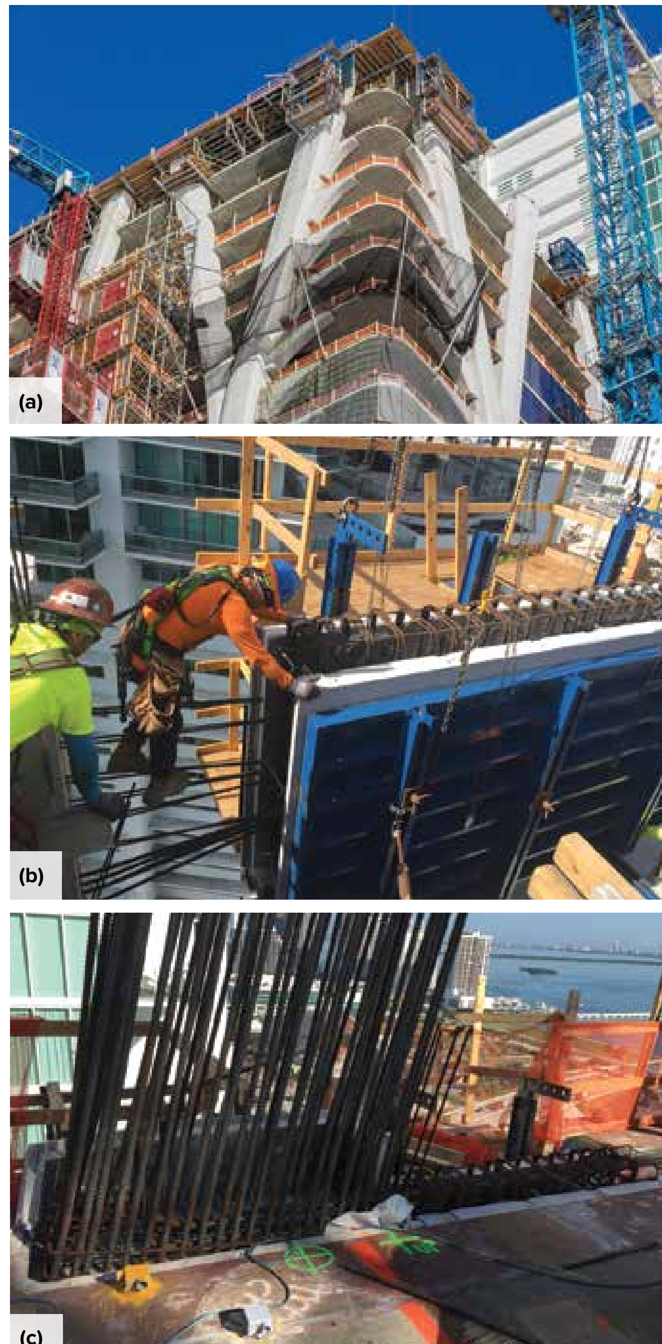


Fig. 5: The shape of the building from level 10 to 32 includes large balconies: (a) the balconies are supported by arch-shaped column brackets *(photo courtesy of ODP Architects)*; **(b) the brackets were constructed using GFRC forms that were assembled around reinforcing cages** *(photo courtesy of Plaza Construction)*; **and (c) the brackets were anchored to the columns** *(photo courtesy of Plaza Construction)*

Managing the Logistics of a Global Construction Team

One of the biggest challenges of the One Thousand Museum project was organizing a construction team that stretched halfway across the world. While the transport of the GFRC panels from Dubai to Miami increased the complexity of project management, both locations had the advantage of being port cities, which minimized overland transportation. APCL's panels arrived in Miami at a staging area managed by local concrete contractor Capform, Inc.

Because of the huge size and weight of many of the panels, the potential for surface chipping and panel breakage during shipment across the Atlantic Ocean was a concern. "We decided to produce foldable steel crates with two hinged side walls and fixed end walls," explains Halvorsen. Most panels were crated and then placed in 40 ft (12 m) long, 9.5 ft (3 m) tall shipping containers that were loaded onto ships.

The building team made sure to have a stockpile of GFRC formwork on hand, always delivered sooner than needed to build time into the construction schedule for potential mishaps or damage to GFRC forms. The project's general contractor, Plaza Construction, had 3 months' worth of forms available at any given time. Only a handful of the thousands of pieces were broken, and they could be repaired on-site using a face mixture.

The construction process took its toll, however, on the GFRC panels' finish once installed. While the finish is fairly robust in that it resists splashing and staining, it had to be washed and cleaned. The cleanup added an additional layer of unexpected expense to the project. The material got a lot of residual dirt and concrete on it. At the end of the project, the face of the panels had to be ground to return them to their original color. However, because the GFRC panels came with an impregnated sealer, the surface grinding did not remove the sealer or damage the finished surface.

Final Remarks

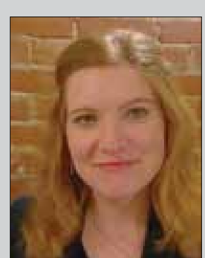
"My biggest takeaway [from this project] was that there is no structure that can be imagined by an architect that cannot be built," says Ramirez. "If you put enough folks in the room and discuss the issues, you're going to come up with a solution." Now DeSimone often asks clients if they have considered using GFRC. "We've proven it can be cost-efficient relative to other alternatives and allows for interesting designs," says Ramirez.

One Thousand Museum will open this summer, 4 years after groundbreaking. Even before completion, however, it's become one of Miami's signature buildings.

Project credits

1000 Biscayne Tower, LLC, Developer; Zaha Hadid Architects, Design Architect; ODP Architects, Architect of Record; DeSimone Consulting Engineers, Structural Engineer; Plaza Construction, General Contractor; Arabian Profile Company Limited, GFRC Manufacturer; ConFab, Local Concrete and Precast Concrete Producer; and Capform, Inc., Concrete Contractor.

Selected for reader interest by the editors.



Deborah R. Huso is Creative Director and Founding Partner of WWM, Charlottesville, VA. Her publication credits include positions as contributing editor with the *Progressive Farmer* and as a monthly columnist for *HousingWire* magazine. She has contributed articles to many other publications, including *Precast Solutions*, *U.S. News and World Report*, *USA Today*, and *Business Insider*, and she has provided website development and content strategy for several Fortune 500 companies.