Architecture as ART

BY SHINJINEE PATHAK, PE, AND VICTORIA G. PONCE DE LEON, PE

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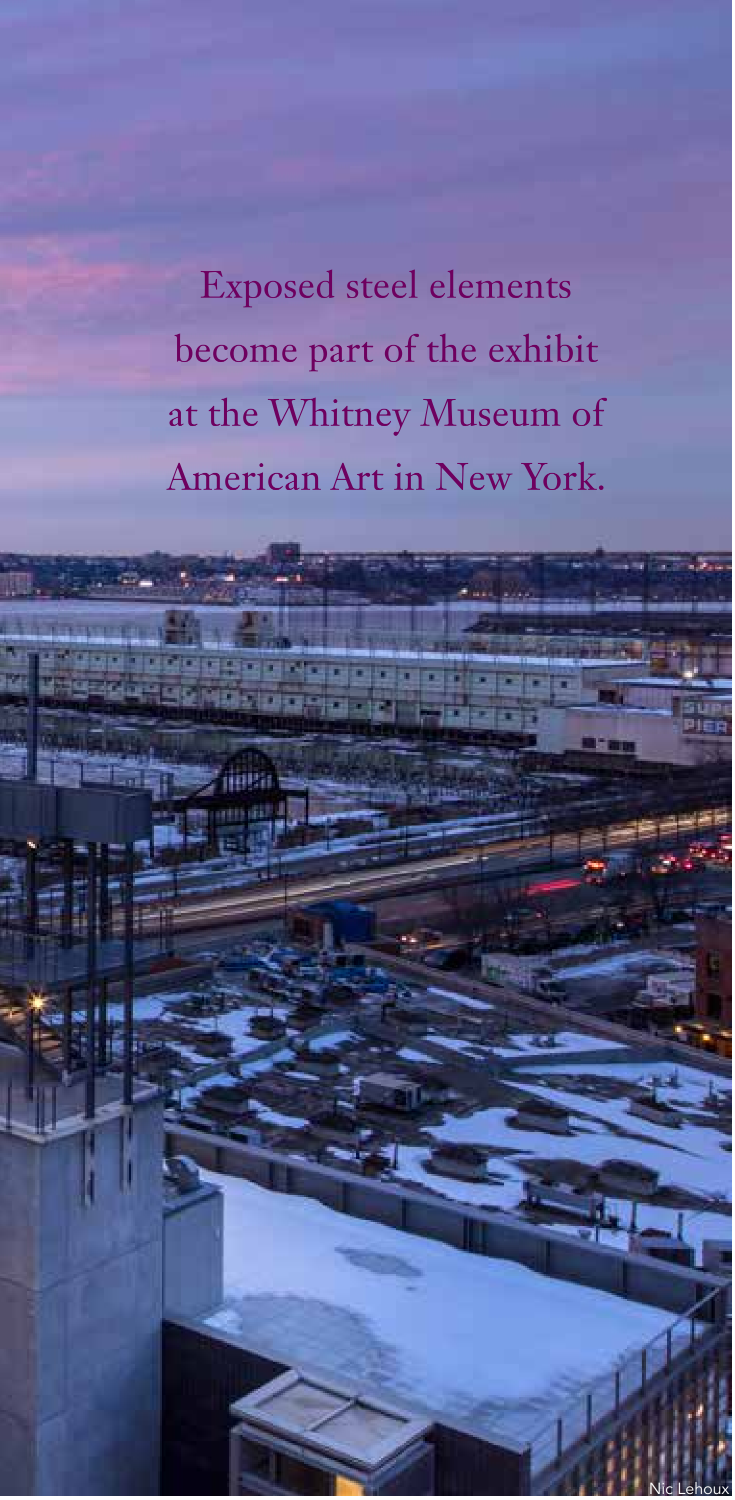
THE WHITNEY MUSEUM OF AMERICAN ART has had quite the journey.

Founded in 1931 by socialite and art patron Gertrude Vanderbilt Whitney, the museum has been located in several spaces in Manhattan. In 1966, the museum moved to its Marcel Breuer-designed home on the Upper East Side with a collection numbering some 2,000 pieces—which has grown to 22,000 pieces today. To better showcase these thousands of modern and contemporary works, as well as to provide ad-

Exposed steel elements become part of the exhibit at the Whitney Museum of American Art in New York.



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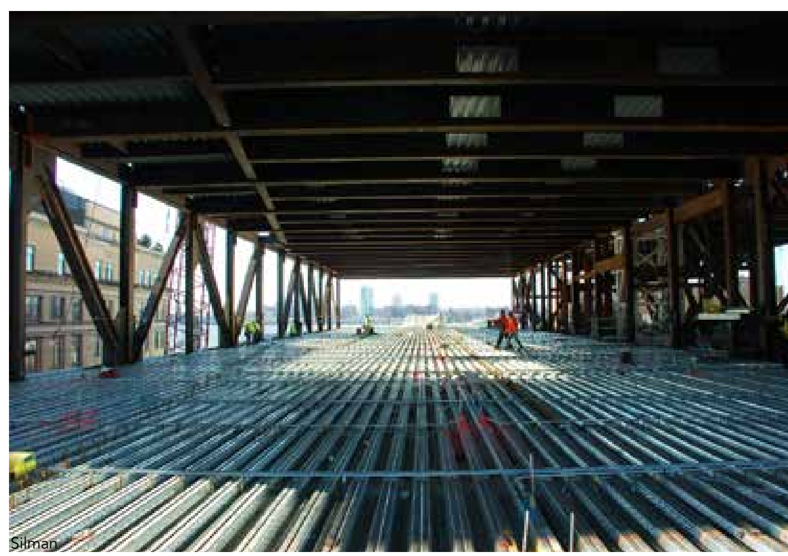

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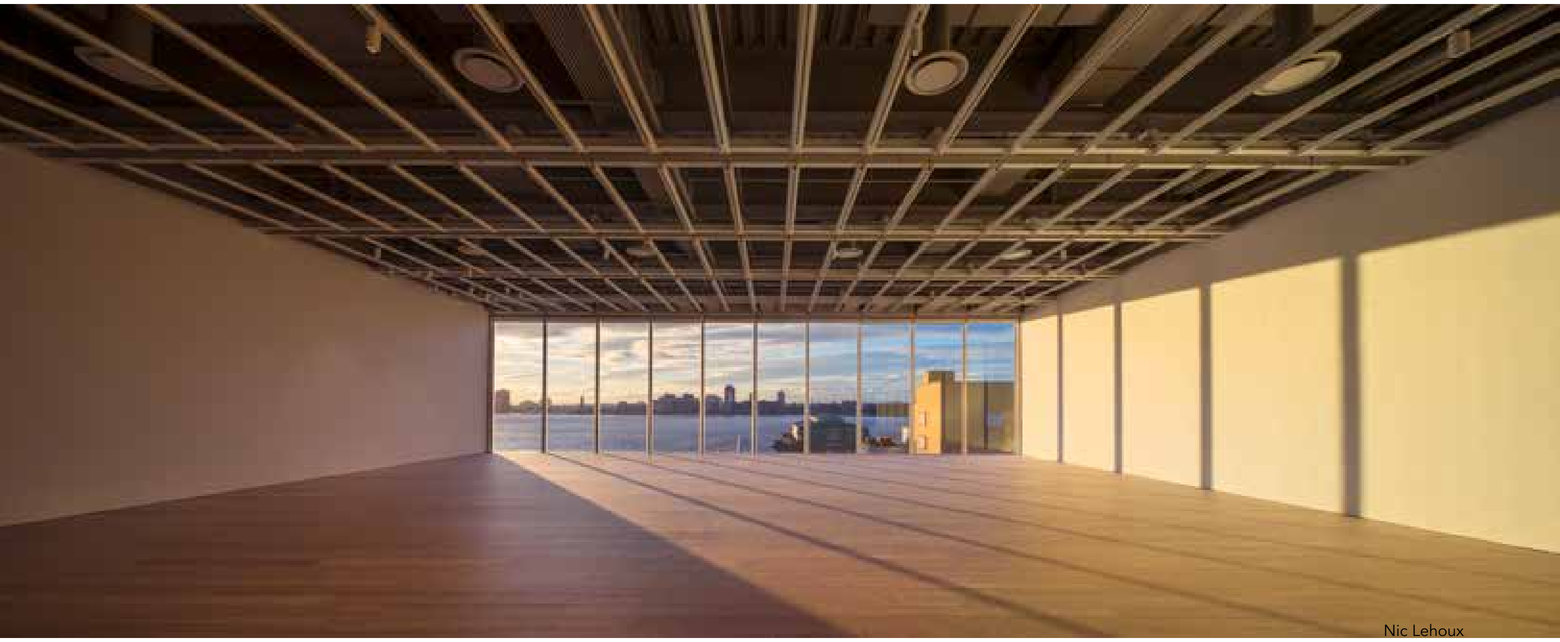
ditional programming space, the museum commissioned a new building located in Manhattan's dynamic Meatpacking District, nestled between the High Line and Hudson River.

The nine-story, asymmetrical building, designed by Renzo Piano Building Workshop (RPBW) features tiers of terraces and glazed walkways that step down to the High Line. Cantilevering dramatically over a public plaza, its set-back entrance opens into a nearly 10,000-sq.-ft lobby. A theater, office, support spaces and expansive new galleries—one of which, an 18,000-sq.-ft column-free space, is the largest open-plan museum gallery in New York City—are located on the floors above. At the top floor, the "studio" gallery and a café are naturally lit by a saw-tooth skylight system. The new building provides over 50,000-sq.-ft of indoor gallery space and nearly 13,000-sq.-ft of outdoor gallery space for the museum.

The structural design for the new Whitney building was developed by Robert Silman Associates (Silman) to provide flexible, open-plan galleries for the museum and to achieve the architectural vision of a simultaneously imposing and inviting urban structure. The typical challenges of coordination were even greater for the design of the Whitney, where high-end architecture meets high-profile artwork. To satisfy the needs of the institution, wants of the architects, demands of the mechanical and electrical systems and limitations of the construction site, Silman was heavily involved in coordination and in some cases, aesthetics.

The superstructure of the museum uses steel framing with concrete-on-metal-deck slabs to achieve the design's requirement for long spans and open spaces. The south half of the building houses the four main galleries on the fifth through



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eighth floors, each with a larger floor plan area than the one above. The open plan layouts programmed by RPBW provide flexibility for movable partition walls and displaying large art installations. The gallery floors were also designed for loads of 50 psf to 100 psf in addition to the minimum 100-psf code-required occupancy live loading to accommodate heavier art installations atop the floor framing or art loads hanging below the floor framing. Three of four outdoor terraces are extensions of the interior gallery spaces, necessitating increased load allowances for supporting art displayed in these areas.

Anchor points on the terraces and north facade of the Whitney are designed to provide flexibility for hanging or bearing large art installations. Silman collaborated directly with the museum to strategically locate the anchor points and design them for an acceptable capacity. Since its opening, the Whitney has retained Silman as the structural engineer for reviewing the structural feasibility and impacts of exhibits and installations.

Seismic System

Although New York is not thought of as a high-seismic area, the building's location on poor soil and its irregular geometry resulted in a seismic-controlled lateral design. The building was assigned to Seismic Design Category D based on the code in effect at the time. However, by performing a dynamic response spectrum analysis, Silman took advantage of an allowance by the *New York City Building Code* to design the building under Seismic Design Category C. In addition to a modal analysis, Silman performed a lateral pushover analysis to confirm that the trusses, which act as lateral elements in addition to supporting gravity loads, were stiff enough to not yield during a seismic event.

A central spine along the architectural core of the building effectively separates the north and south diaphragms. The locations of the lateral frames on the south side of the building were limited by the large open galleries on the south side of the core. These limitations on the frame locations introduced load path discontinuities as well as transfer elements (beams and trusses) at nearly every floor. The geometry of the building's lateral system also created torsional irregularities, diaphragm discontinuity, a weak story, a soft story and both in-plane and out-of-plane offsets in the lateral system, such that most lateral elements were designed for over-strength, thus requiring several very large structural members. W14 sections were used for the majority of the columns and braces, with the largest section being a W14×500.

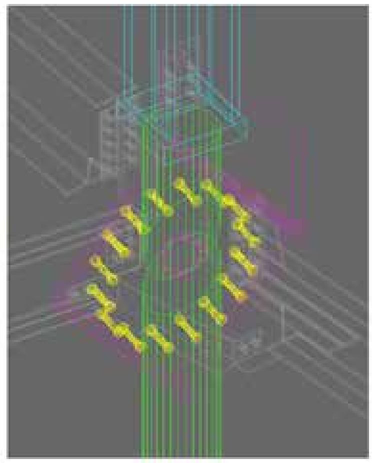
Clever Cantilevers

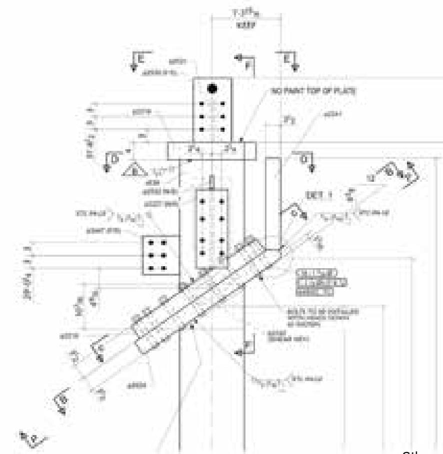
Large cantilevers serve as both structural elements and architectural features of the building. The five upper stories cantilever in two directions over the lower four floors. The 25-ft-long to 80-ft-long cantilevers are achieved with a full-story truss that spans along the south side of the fifth-floor gallery. The south truss is supported from north-south spanning two story trusses, with top chord framing of 46-in.-deep built-up plate girders. These north-south spanning trusses are left exposed in the office spaces on the fourth and third floors.

At the front of the building the north-south trusses are supported by slender, architecturally exposed structural steel (AESS) round columns. These vary in height from 15 ft to 55

Handling Mechanical

The mechanical, electrical and plumbing (MEP) systems for an art museum are by necessity extensive and, as a result, can be very heavy. Silman coordinated with the architect and MEP engineers to keep main ducts aligned and sized the steel beams to allow for large web penetrations spaced evenly in the main galleries where structural framing is exposed in the ceilings. The double-height basement space houses the majority of the mechanical units and piping, much of which was laid out during the construction phase of the project. To avoid overstressing the slab on metal deck flooring system, anchor points and loading for all hanging MEP equipment were individually reviewed for structural impact and coordinated between Silman and the contractor.





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▲ A connection detail for one of the complex exterior column assemblies.

ft and are 15 in. in diameter, with the exception of the tallest column, which is 22 in. in diameter. To maintain the small diameter relative to their height, the majority of the columns were designed as exposed round hollow structural sections (HSS), while the more heavily loaded HSS columns—such as the 55-ft-long, 22-in.-diameter column at the building's southeast corner—were filled with high-strength concrete and vertical rebar for increased strength and stiffness. (Some of the 20-in. and 22-in. round columns used on the project are actually solid steel, not HSS.)

These columns and their top and bottom connections are exposed within the lobby space, so their appearance was vital to RPBW's design; the lobby columns alone account for approximately 150 tons of steel. The slope and skew of the building facade extends to the column splice plates, creating complex three-dimensional connections that transition between the interior and exterior spaces. Silman used Rhinoceros' 3D modeler to understand the geometry for detailing the plates, bolts and thermal breaks, and worked closely with the steel detailer as well as the steel fabricator, Banker Steel, to understand any constructability concerns.

The facade of the Whitney Museum consists of three different systems: precast, steel panels and glass. Steel panels (manufactured by Gartner)—⅜ in. thick, 3 ft., 4 in. wide and up to 60 ft long—clads much of the exterior of the building. These panels are hung from the top and braced back laterally at each floor. The beams supporting the panels for gravity at the top were designed for the full weight of the panel, and the lateral connections provided redundancy to support the weight of the panels in the unlikely event that an upper connection fails.

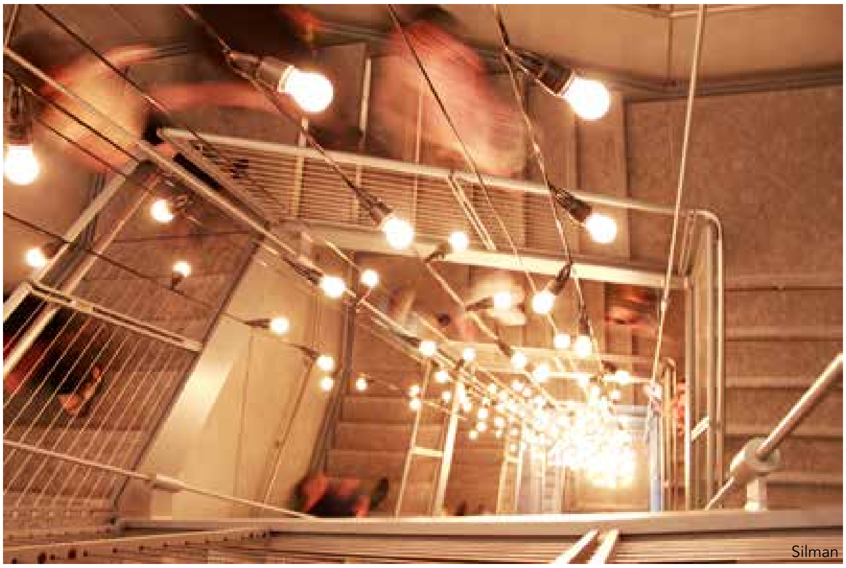
A glass wall supported by a cable system wraps around the first-floor lobby and restaurant. Following the sloping profile of the lobby ceiling, the cable wall ranges in height from 24 ft to 45 ft, with tension points ranging from 20 kips to 85 kips. In the initial coordination of the glass cable wall and structural support, performed in cooperation with curtain wall consultant Heintges and Associates, Silman provided load path assumptions, deflection expectations and stiffness values of the primary building structure. In return, Heintges provided tension forces in the cables and the resulting loads imposed on the structure above and below. After several iterations to fine-tune the cable wall system and supporting structure, the connections were designed to allow for field adjustments to the pre-stressing of the cables.

Stunning Stair

The interior feature stair, which spirals up from the lobby to the fifth-floor gallery, is possibly one of the most photographed spaces within the museum, partially due to the ethereal art installation (by Felix Gonzalez-Torres) cascading down its central open core. Throughout the design process, Silman collaborated with RPBW to provide a stair that was aesthetically pleasing, designed for the strength requirements of the local building code and dynamically satisfactory from a user-comfort perspective. The stair stringers are solid 2.75-in.-thick by-9-in.-thick routed plate profiles supported at two points on each side by steel plates that knife through the 6-in. precast panel architectural walls on three sides of the stair. The stair is also supported around its central core by 0.75-in.-diameter rods hung from steel beams between the fifth and sixth floors. Two of the four rods are connected to the first-floor structure by a custom spring clevis, and the rods are coupled at each floor by a custom connection (both the clevis and connection were designed by TriPyramid). The stone stair treads are designed to act compositely with the steel plate below the tread that spans down the center from stringer to stringer.

Due to the architectural requirements of the building design, the structural design team had to be adaptable and creative in the design of the structural system and, in many cases, take the lead on coordination to acquire and incorporate information from all parties. The team worked tirelessly to coordinate between the design consultants and construction

➤ The interior feature stair spirals up from the lobby to the fifth-floor gallery.



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personnel and find solutions to all of the challenges, all while keeping the goals of the museum as the top priority. The result is a building where structure is on display, enhancing both the architectural design and the art within. ■

Owner
Whitney Museum of American Art, New York

General Contractor
Turner Construction, New York

Architect
Renzo Piano Building Workshop, Genoa, Italy

Structural Engineer
Silman, New York

Steel Fabricator
Banker Steel, Lynchburgh, Va. (AISC Certified Fabricator)

Close Call

In October 2012, the project received a bit of a wake-up call. With the building foundations substantially completed and the superstructure construction ramping up, Superstorm Sandy hit New York and flooded the Whitney site.

With the installation of the first-floor framing was nearly complete, it was clear that simply reinforcing the floor structure and glass cable wall for a higher flood elevation would not be sufficient; the building would require a robust system of barriers, gates and flood doors to protect it and the artwork inside from future flood events. Silman helped design the attachments of this system, collaborating with Cooper Robertson Partners (CRP) and RPBW to architecturally integrate these attachment points into the building's design.

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▲ HSS X-bracing.

➤ The steel-supported exterior stair and observation deck.

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