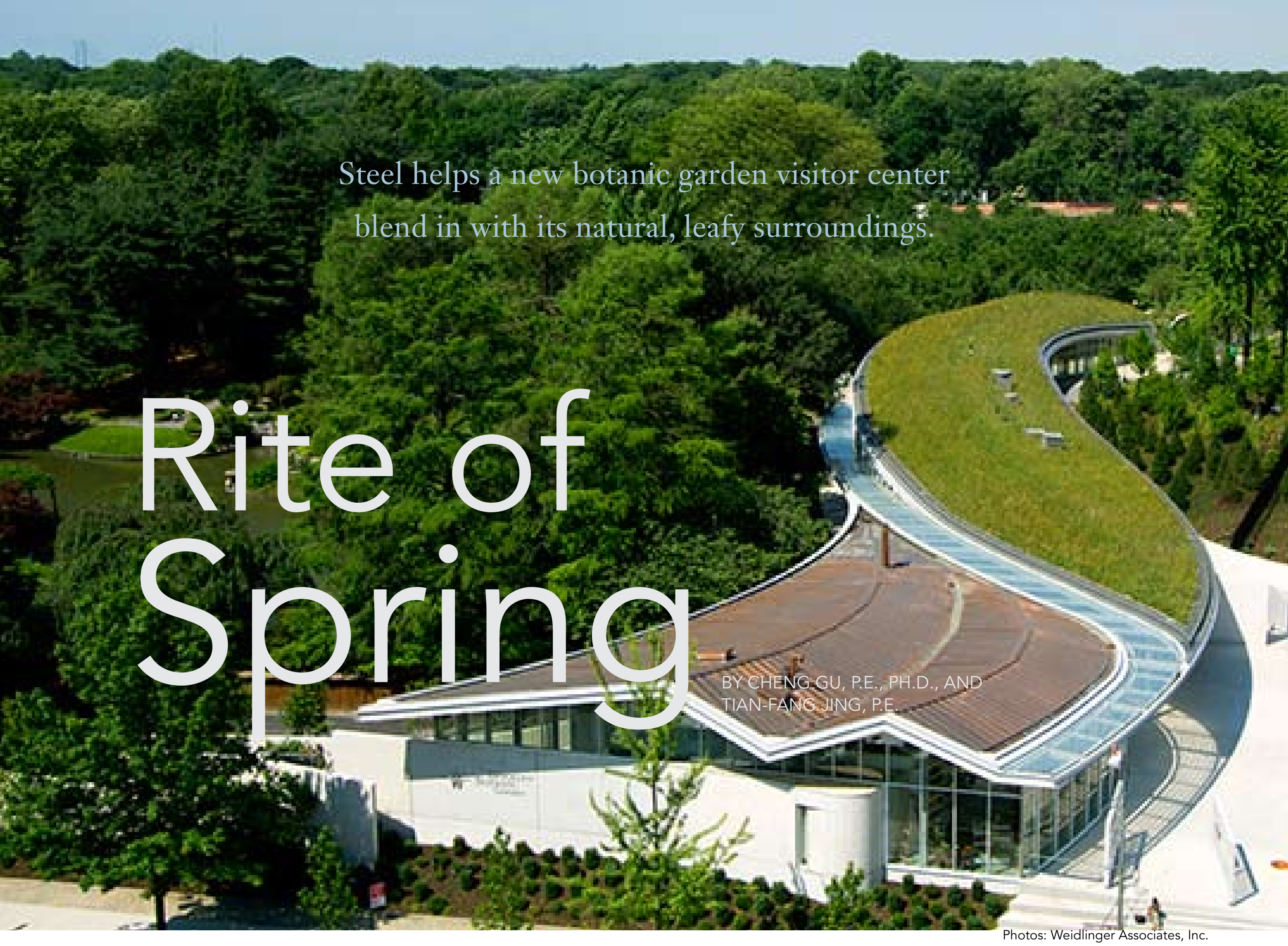


Steel helps a new botanic garden visitor center blend in with its natural, leafy surroundings.

Rite of Spring

BY CHENG GU, P.E., PH.D., AND TIAN-FANG JING, P.E.

Photos: Weidlinger Associates, Inc.

APRIL SHOWERS bring May flowers, or so the saying goes.

At the Brooklyn Botanic Garden (BBG), it wasn't just the flower petals that opened this past May. The 100-year-old independent nonprofit institution also celebrated the grand opening of its long-anticipated Visitor Center. Providing a new, modern portal to the historic garden, the opening was a major milestone in BBG's campaign to upgrade the garden for the next century.

A 417-ton steel superstructure was chosen for the iconic 20,000-sq.-ft building, which was required to conform to a curvilinear, asymmetrical site and support an alluring leaf-shaped green roof. A glass and steel envelope that controls transparency and creates a pleasing pattern of shadows on the interior brings the landscape inside the building, a major goal of the project.

The original BBG master plan called for the building to be placed in the center of a 25-ft-high berm on the site's north side, necessitating removal of the ginkgo tree allée on top of it. Architect WEISS/MANFREDI instead proposed that the structure bisect the berm and merge into it. This solution made the building a natural extension of the berm, in harmony with and seeming to disappear into the living garden topography. Moreover, it preserved the mature ginkgo trees and incorporated the berm as an organic geothermal mass for insulating the building.

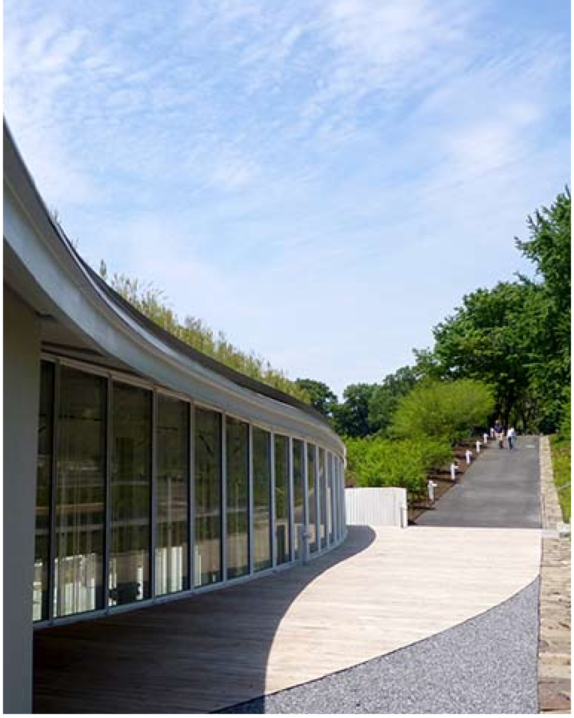
The building fits snugly into the berm and responds to the undulations and constraints of the adjacent Japanese Hill-and-Pond Garden to the south. Only the east side of the building, which borders Washington Avenue, is accessible from the street, while the west side is accessible from both the Garden and from the elevated Overlook and Ginkgo Allée at the top of the berm.

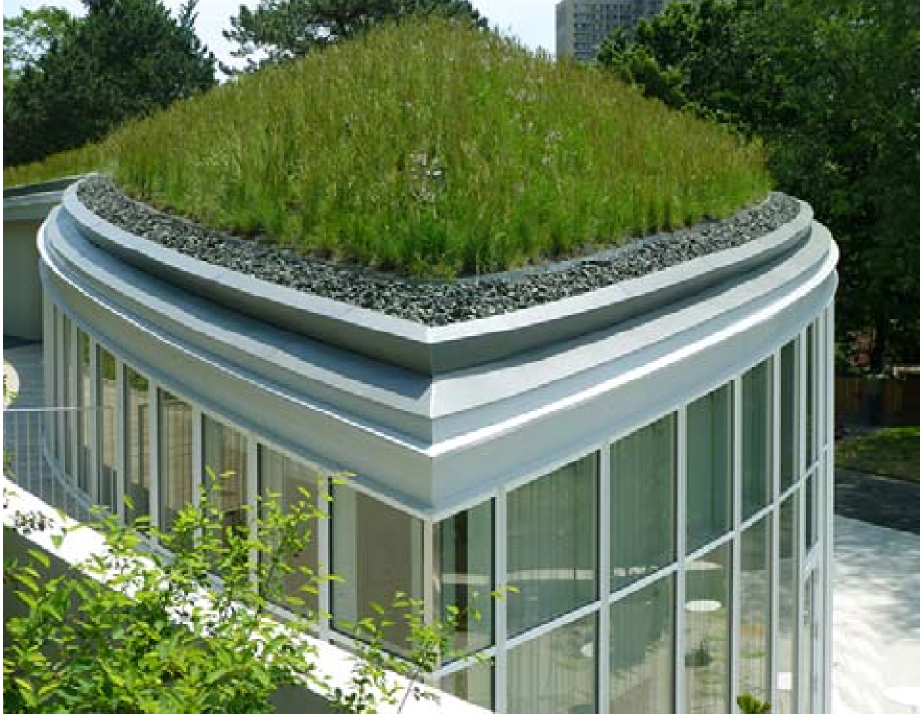
A Balancing Act

One of the major responsibilities of Weidlinger Associates, Inc. the project's structural engineer, was to keep costs in line despite the structure's complex geometry and construction challenges—which meant finding innovative structural solutions that respected both the architectural vision and economic reality.

The building's main components are a single-story retail pavilion (with basement), shaped like a half-open bud, and a double-height, leaf-shaped exhibition and events pavilion. The two pavilions are connected by a sinuous trellis-like glazed canopy. Above the gift shop is a double-pitched copper roof, representing a giant autumn leaf, and a single-pitched, leaf-shaped living roof garden (280 ft long; 10,000 sq. ft) tops the events space; the roof garden boasts more than 40,000 seasonal plants. The copper roof, which will age to green, echoes the roof of the BBG's landmark 1917 administration building, designed by McKim, Mead & White.

While steel was optimal for the asymmetrical geometry and for providing a versatile column-free space layout, structural design was still a delicate and constant balancing act to keep the project from becoming prohibitively expensive. (Architectural concrete was used for exposed walls and other elements, and conventional concrete for unexposed foundation walls, slabs and footings.) For the steel framing system, Weidlinger's main strategies were to simplify the building's geometry, reduce the cantilever span of roof rafters and reduce the total weight of the steel. Twenty-nine straight grid lines, each with a different angle, were used in the building's short direction, and 10 curved grid lines were used in the long direction.





The upper breezeway of the building.

The leaf-shaped exhibition and events pavilion.

The structure features a 280-ft-long, 10,000-sq.-ft living roof garden.

Straight vs. Curved

The topography of the curved roof structure became an interplay of straight and curved steel. The aim was to produce as smooth a curve as possible while using as many straight elements as possible, in order to reduce cost. Twenty-nine partially exposed, hollow structural section (HSS) rigid frames with full-penetration welded moment connections form the backbone of the superstructure. One important, budget-conscious decision was to support the warped roof deck with straight bent rafters rather than with arches that followed the curvature of the roof. The spans of the rafters range from 12 ft to 36 ft, each one with a different slope.

For the roof, a 16-gage 1½-in.-deep roof deck made the most sense, because it was shallow enough to warp in one direction (to produce the curved shape), but its gage was heavy enough to support the saturated soils and plants of the green roof.

A serpentine C12×25 architecturally exposed steel channel at the perimeter of the roof, highlighting the leaf shape, was an additional challenge. The channel weaves along the building's edge, functioning at various points as a roof edge, steel trellis and the stringer of a cantilevered ornamental stair. It was coated first with a Platt Zinc 85/15 shop primer, then with Tnemec Epoxiline N69F shop intermediate coat and finally with a Tnemec 1081 Endurashield top coat. To increase constructability and reduce cost, it was divided into 50 segments rather than 100 segments by interconnecting each one to three HSS outriggers.

Long vs. Short

The building is 320 ft long but varies in width along its entire length, giving it an unorthodox shape. At the building's eastern end, it is approximately 60 ft wide; at its western end, the two sides gradually converge to a point. Construction sequencing was crucial because access, only 4 ft in some places, was difficult. While the longest possible cantilevered roof rafters were preferred by the architect, length added cost and increased the difficulty of smoothing the C12 channel. In the final design, the spans of the cantilevers were scaled back to about 10 ft in an effort to be to be more cost-efficient, without compromising aesthetics.

Precise vs. Tolerant

Another challenging structural task was attaining the required tolerances for the C12 channel connections to the roof structure, which consists of various regions with different cantilevers and loads. In the initial design, precise ½-in. flat-head bolts were supposed to connect the channel to the HSS outriggers. The tolerance adjustment was made from the steel setting blocks behind the channel on the assumption that the channel would be the last element to connect to the structure after the roof was fully loaded.

Cheng Gu is an associate and **Tian-Fang Jing** is a principal, both with Weidlinger Associates, Inc. Gu, the project manager for the Brooklyn Botanic Garden Visitor Center, has worked with Jing on many cable-supported fabric roofs and other long-span and special structures in the U.S. and worldwide. Currently, they are collaborating on an upgrade of the Javits Center curtain wall and space-frame roof. They can be reached at **cheng.gu@wai.com** and **tian-fang.jing@wai.com**, respectively.

▲ The building entrance during construction...

▼ ...and after completion.

During the contractor's bid walk-through, however, the plan was altered to install the channel via welding, which was the steel erector's preferred method of installation. This required revisiting the 3D SAP models and the roof-edge deflections, resulting in a different "high-set" at the cantilever tips to cancel the deflections under normal dead load. In the final configuration, puddle welds replaced the flat-head bolts in the connection details. As the loads of the green roof vary through dry and wet seasons, the roof edge will deflect within ¼-in., which is not visually noticeable.

HSS vs. W-Shapes

A custom-made curving glass canopy was used to create a covered breezeway that partially shades the entry plaza. The canopy is composed of 46 ceramic, fritted, low-iron, laminated glass units, which allow natural light to pass through it. Two types of trellis grids support the canopy: HSS8×4 longitudinal with HSS5×2 cross members for the longer sections; and HSS6×4 longitudinal with HSS4×2 cross members for the shorter ones. These were all fully shop-welded and installed between the HSS10×6 steel outriggers that penetrate through the glazed curtain wall. Between the HSS rigid frames for the rest of the roof, a system of wide-flange filler beams expedite warping of the steel deck. The beams use light W10×12 elements wherever possible and heavy W6×25 elements when ceiling height is restricted. The majority of the canopy's steel members are straight.

Exposed vs. Concealed

The decision to expose more of the structure was due to budgetary reasons, but there were also secondary gains. Some heavy HSS12×6 roof rafters, which were originally concealed behind the architectural finish, were replaced by light HSS18×6×$\frac{5}{16}$ rafters, exposed at the bottom. The benefits were reduced cost, a stiffer roof structure and embellishment of the leaf-patterned ceiling with visually interesting branched ribs. The gift shop's HSS columns and bend rafters were also exposed, as were its hanging grids for ducts and lighting, another aesthetic plus. The building's architecturally exposed HSS10×6 columns, which march east to west in a curvilinear configuration, are reminiscent of the rows of ginkgo trees on the berm.

Stand-alone vs. Integrated

An integrated approach involving close collaboration among architects, engineers and contractors produced a splendid jewel, but one that is understated, well integrated and sustainable. The overall $28 million project construction cost was relatively modest, considering that it also included soil removal, site improvements, new utilities, landscaping and green roof plantings. This investment in building and infrastructure should increase in social and economic value over time.

Weidlinger's civil engineering team also contributed to the project's long-term worth. Twenty-eight geothermal wells were installed to help the building breathe and cycle with a reduced energy consumption. Three bioinfiltration basins were constructed at the front entry plaza and rear garden plaza of the building to retain stormwater and filter it to the adjacent Japanese Hill-and-Pond Garden, facilitating the garden's larger ecosystem. These sustainable measures allowed the team to apply for LEED Gold certification.

A final highlight of the project, which further demonstrates its seamless integration with the overall landscape: From the entry plaza on Washington Avenue, the building seems to be a simple one-story structure, but despite its transparency, it guards a "secret." Following the path under the glass-lit trellis toward the garden, a visitor can climb an exterior curved staircase to an overlook landing outside the events space, for a view of the building's double-pitched copper roof and the Japanese Hill-and-Pond Garden. Structurally, the curved steel stairway is connected to the outrigger of a pedestrian bridge that creates an upper terrace level cutting through the events space and exhibition gallery. Crossing this upper breezeway is a hidden path under the green roof that leads to the top of the newly planted berm and Gingko Allée, and then to the hilltop Overlook with all-encompassing views of the 52-acre Garden. MSC

Owner
Brooklyn Botanic Garden

Architect/Site Design
WEISS/MANFREDI Architecture/Landscape/Urbanism, New York

Structural Engineer
Weidlinger Associates, Inc., New York

Construction Manager
The LiRo Group, New York

General Contractor
E.W. Howell, New York