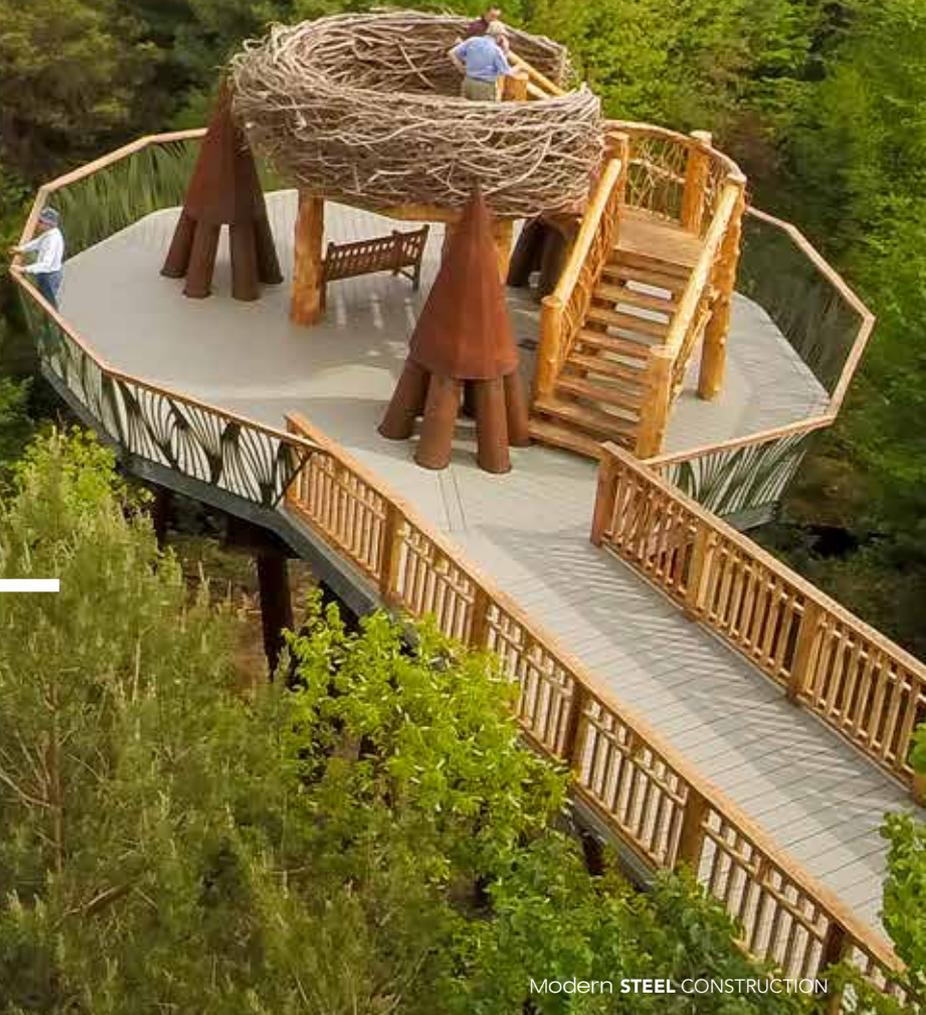


Once again, it's time for *Modern Steel Construction's* annual compendium of fun projects showcasing steel.

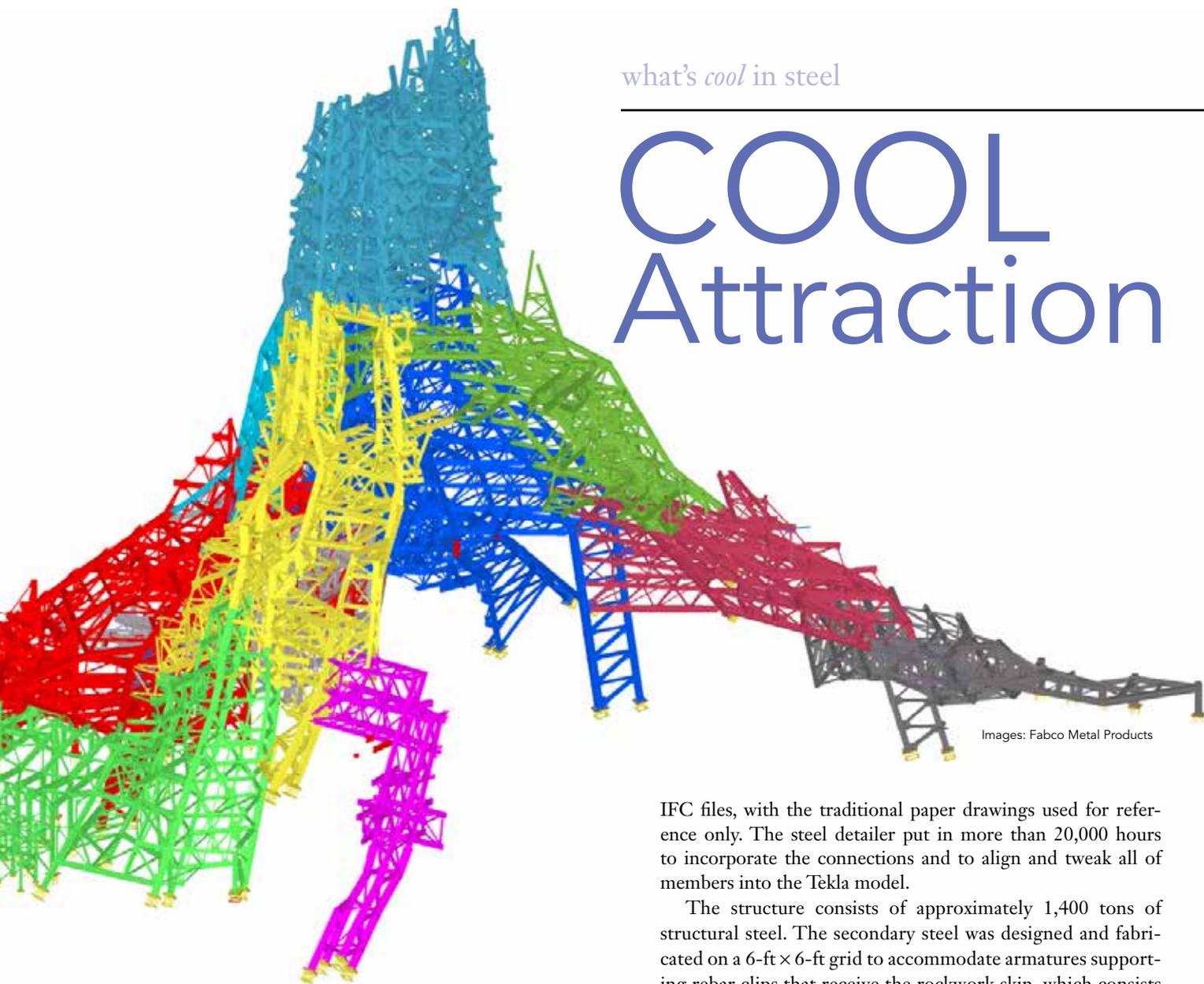
This year's Cool List takes us deep into history, deep into a volcano and deep into the woods.

what's  
*cool*  
in  
STEEL



what's *cool* in steel

# COOL Attraction



Images: Fabco Metal Products

**THANKS TO** Orlando is known the newest, at framed volcano, for the new



**ALL** of its amusement parks, for unique structures. One of Universal Orlando, is a steel- which serves as the centerpiece Volcano Bay water park.

Designed by structural engineer GRAEF and fabricated by Fabco Metal Products (an AISC member and certified fabricator)—and filled with waterslides, not lava tubes—the 200-ft-tall volcano is formed with space frames consisting of a series of vertical bent trusses that rotate around multiple vertical axes. These trusses span various lengths and are interlaced with secondary framing to support multiple platforms. To maintain consistency, all of the members were W14 shapes, ranging from W14×30 to W14×398.

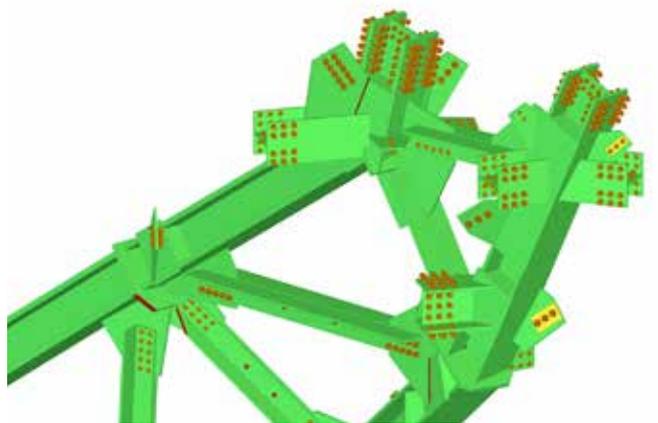
The complicated geometry of the project made it impossible to use traditional hard copy drawings to clearly document the framed members. Therefore, the volcano was analytically modeled using finite element software that interacts with Revit (Autodesk) to accurately capture its complexity. The model was then exported from Revit, via the IFC file format, to Fabco so that shop drawings could be generated in the Tekla model.

The engineering deliverables on the project were these 3D

IFC files, with the traditional paper drawings used for reference only. The steel detailer put in more than 20,000 hours to incorporate the connections and to align and tweak all of members into the Tekla model.

The structure consists of approximately 1,400 tons of structural steel. The secondary steel was designed and fabricated on a 6-ft × 6-ft grid to accommodate armatures supporting rebar clips that receive the rockwork skin, which consists of a shotcrete base and a plaster top coat. Due to the geometry of the design, no two pieces were alike. Because much of the structure is in a consistently wet environment, all of the framing was hot-dip galvanized. Approximately 90,000 bolts were used to connect the frame. Due to the tight tolerances required, round holes and slip-critical connections were used for the connections, which made fabrication and erection challenging. On top of that, all truss and secondary framing connections used skewed plates, so Fabco workers had to use the holes in the plates as the contact points. The workers used iPads during every step of the fabrication process, which was a must for this project.

The erector, Coastal Steel, Inc. (AISC member and certified erector) preassembled as much of the framing as possible on the ground in order to minimize connections that would need to be made in the air. Since the entire structure slopes in multiple planes, it was imperative to minimize deflections until the steel could be supported at the shoring towers. In addition, Coastal had to install the waterslides and their supports within the structure during the sequential erection.



what's *cool* in steel

# COOL Roof



Thornton Tomasetti

**THE EPIC SYSTEM CORPORATION'S** Deep Space Auditorium dug deep to accommodate the healthcare software developer's spatial needs.

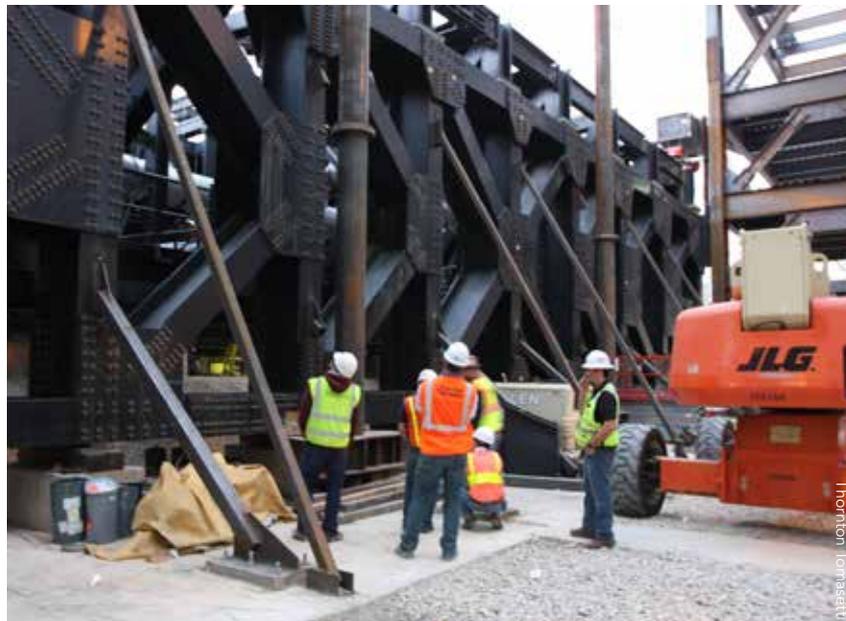
Designed by Cuningham Group Architects and Thornton Tomasetti, the 1.2-million-sq.-ft auditorium is located on the company's 800-acre campus in Verona, Wis. It can seat 11,400 and can expand to accommodate 14,000. Excavated into a hillside to preserve views across the campus, the auditorium extends 74 ft underground and is covered by an eight-acre green roof with vertical glazing for daylighting. The column-free, long-span roof is supported by 25-ft-deep trusses spanning 275 ft.

The auditorium is pie-shaped with 12 radial trusses spanning approximately 270 ft and sloping to a 100-ft-long header truss. The truss and its supporting columns used the newly available W36x925 shapes in ASTM A913 Gr. 65 material.

Unique load considerations, including soil and gravel depths of up to 8 in., and erection issues had a strong influence on the roof's design. To ensure an efficient structure and limit potential conflicts during construction, Thornton



Cunningham Group



Thornton Tomasetti



Thornton Tomasetti



Thornton Tomasetti



Thornton Tomasetti

Tomasetti proposed an innovative approach that integrated temporary works to erect the 4,200-ton roof.

Typically, a long-span roof is the last element of a structure to be constructed but in this case, reversing the sequence would accelerate procurement and fabrication of the steel as well as completion of the facility. The project team employed a roof-lift approach, achieving construction efficiency and increased safety by eliminating the need for expansive and tall shoring and construction at elevation. The lift also allowed the use of smaller, more economical equipment and less manpower.

Prior to the lift, all truss end connections and their support points were scanned to verify that the structure would fit when put in place. The roof and superstructure were designed to allow roof framing to be assembled on the ground, then the roof was then lifted 59 ft into position via 18 custom lift platforms, lift boxes and temporary connections, all modeled and fabricated using Tekla. The models were housed on a cloud server, enabling the fabricator, LeJeune Steel Company (an AISC member and certified fabricator) and Thornton Tomasetti to work simultaneously on the development. Steel detailing was provided by LTC, Inc., an AISC associate member.

This inventive use of technology expedited the manufacturing and delivery of the temporary works and permanent structures and played a crucial role in meeting the tight 29-month design and construction schedule, which otherwise would have taken an estimated 12 to 18 months longer.

what's *cool* in steel

# COOL Mezzanines



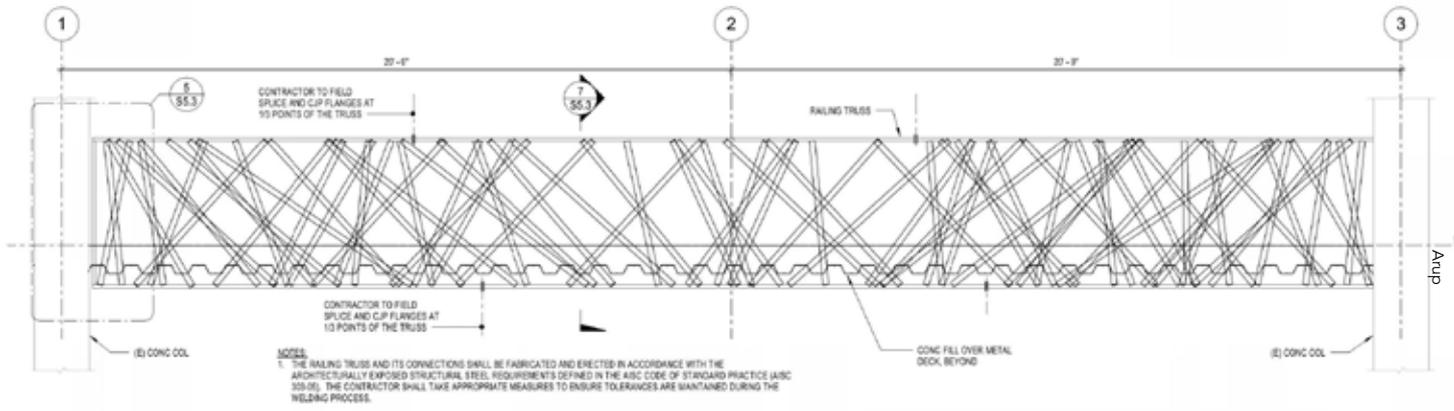
**THE SAN DIEGO** Natural History Museum's striking new steel mezzanines are a distinctly modern homage to the beauty of the natural world.

Designed by PLACE Architecture and Arup, the twin mezzanines are a key feature of the museum's newly renovated Special Collections Gallery, which showcases rare works by noted naturalists and artists like John James Audubon. Supported by artistically engineered, visually prominent steel trusses that call to mind river reeds swaying in the wind, the mezzanines are a prime example of how great design emerges from creative approaches to complex engineering challenges.

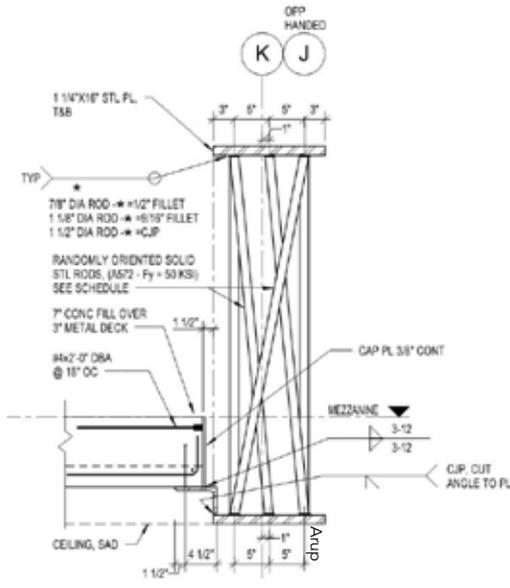
The primary engineering challenge involved finding a structurally elegant approach to introduce 2,000 sq. ft of additional space to the building's 19-ft-high second story. PLACE's preferred design solution was a mezzanine, but this was complicated by the fact that the existing second-floor structure could not be modified to support additional column loads. Arup's design engineers proposed using exposed steel trusses comprised of plate chords and rod webs, spanning more than 40 ft between the building's existing columns. Supporting the mezzanine at the bottom chord plate allowed for the use of upturned trusses, which could do double duty as guardrails while also preserving height on the lower floor, noted Bruce Danziger, Arup's structural engineer of record for the project. Moreover, Danziger said, the open-web trusses offered the benefit of preserving a feeling of openness and clearer sightlines.

The design team quickly recognized that in addition to providing the necessary support, the structural steel could be used to imbue the new gallery with unique architectural character. To facilitate this design initiative, PLACE and Arup worked together to develop an iterative, parametric design methodology using a data exchange between structural analysis software GSA, 3D design software Rhino and Rhino's parametric design plug-in, Grasshopper. The parametric modeling allowed for rapid virtual prototyping of the truss structure. Various web rod diameters, spacing configurations and angles were tested to arrive at an optimized configuration that was both structurally efficient and aesthetically striking.

The final truss design employs an array of 76 round steel rods, welded to 1¼-in.-thick steel chord plates at the top and bottom, with each individual rod sloped in two planes, in a semi-randomized pattern. Rod diameters vary between 7⁄8 in. and 1½ in. depending on the demand force of each rod, and rod density was maximized at the truss ends to meet high shear force demand. To ensure occupant comfort, Arup carried out footfall analyses of the mezzanine floors and trusses, and each rod was sized to meet combined axial and bending load requirements to keep footfall vibrations within acceptable limits and satisfy global deflection limits under both dead and live loads. The A572 Gr50 steel used for the truss elements is protected by spray-applied fire-resistive material (SFRM) and topped with a finish coat. ▶



1 ELEVATION  
12' x 14'





Tim Smith



Tim Smith

what's *cool* in steel

# COOL Mezzanines

Support for the trusses had to be integrated into the existing structure to resist loads both in the plane and perpendicular to the plane of the truss, noted Toshiyasu Yoza, SE, Arup's lead engineer for the project. The mezzanines' floor structures comprise 3-in. steel deck topped with 7-in.-thick reinforced concrete that spans 20 ft between the rail truss and a steel channel supported by existing columns at the two ends, and a double-angle hanger system at intermediate points. The double-angle hanger system is in turn supported off of the existing beams at the roof level.

The steel trusses were preassembled off-site, and appropriate measures were taken to minimize any distortion resulting from the asymmetric welding of the web rods to the chord plates. Once each truss was fully assembled and checked to ensure that it met specified tolerance thresholds, it was cut into three segments to ease transportation and handling. The truss parts were brought in while the museum was in operation, with minimal disturbance. They were welded back together in situ, then hoisted into place using the existing roof beam above, precluding the need for heavy lifting equipment.

Rather than being limited by design constraints, Arup and PLACE Architecture saw the renovation space as an opportunity for innovation. The end result is an ingenious design that is both functionally robust and aesthetically in tune with the museum's mission to celebrate the natural world.

"The steel trusses solved a structural problem in a visually pleasant way that adds greatly to the ambiance of the space," said Dr. Michael Hager, former president and CEO of the museum, who was instrumental in developing the new exhibition. "The open, nature-inspired feel of the library, made possible by the steel trusses, produces a calm, subdued manner in visitors that allows them to absorb the importance of the historic texts and art on exhibit."



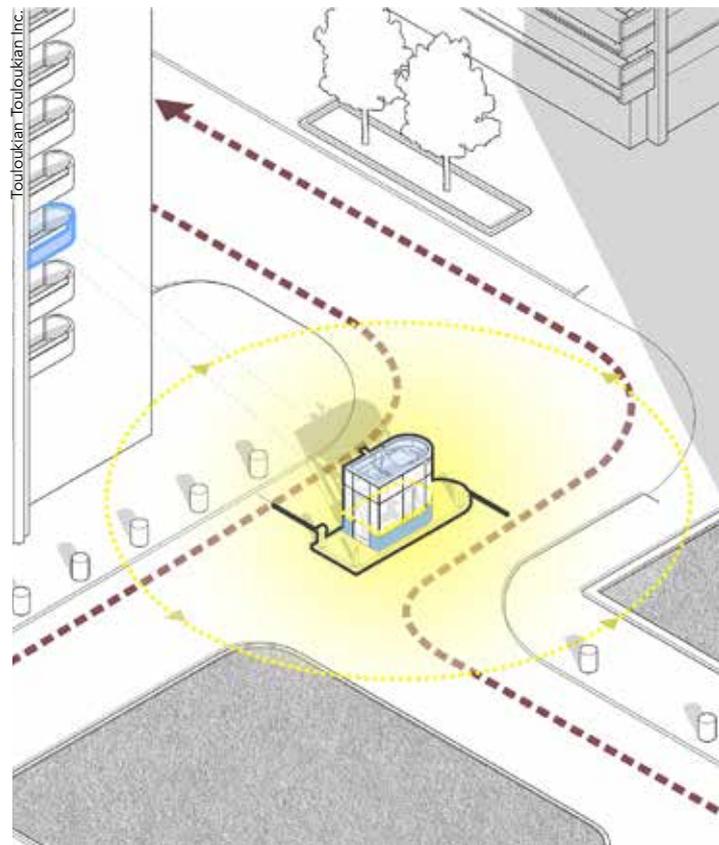
what's *cool* in steel

# COOL Gateway

**A NEW SECURITY GUARDHOUSE** in Boston plays gatekeeper to architectural giants.

Situated between the I.M. Pei's Harbor Towers on the city's waterfront, the small but important structure is modern and functional and was designed by Touloukian Touloukian, Inc., and Richmond So Engineers. Its form respects the aesthetics and design rules of the site by being a direct, formal reference to the towers' balconies.

To maximize sight lines for security personnel, a structural steel frame with custom glass detailing was installed on top of low precast walls. With thermal transfer through the structural steel frame being a primary concern, the design team enhanced thermal performance with details such as nonstructural slots in the steel framing (to be filled with insulation); warm-edge spacers between the glass and steel; and fiberglass reinforced shims between concrete and steel interfaces. The thermal improvements were validated in THERM software in the form of 2D building heat transfer modeling outputs—good news for security personnel working in Boston's typically harsh winters.





Toulooukan Toulooukan Inc.



Toulooukan Toulooukan Inc.

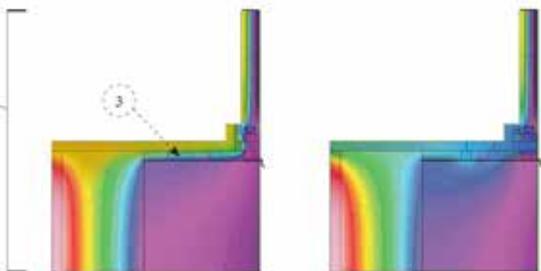
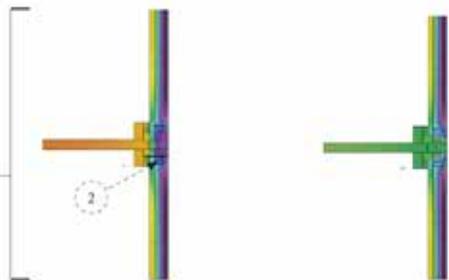
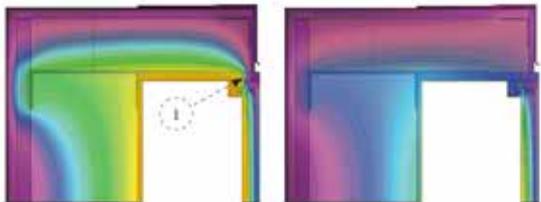


Anton Grassi

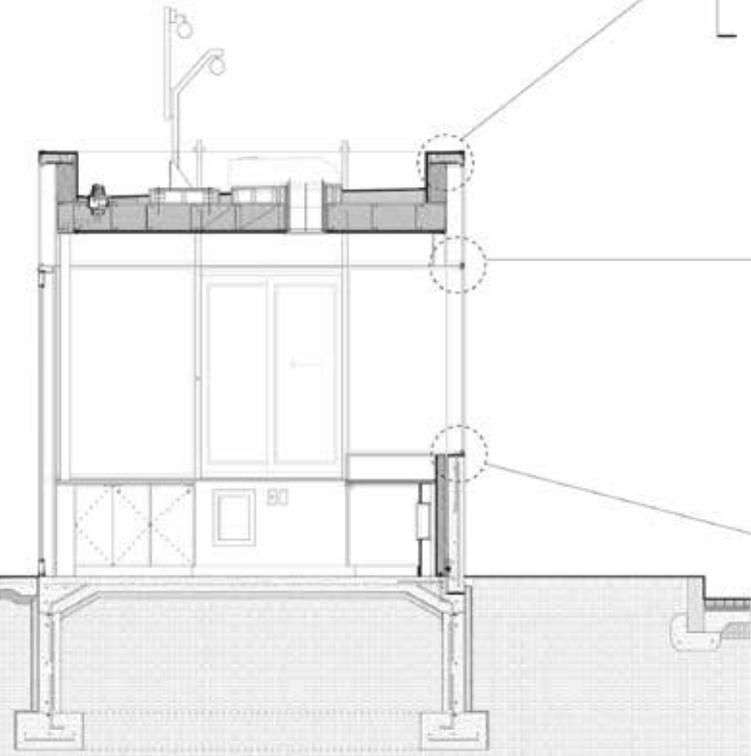
Thermal improvements to the steel frame:

1. Slots were cut in structural steel plates filled with mineral wool insulation to create a thermal break.
2. Warm-edge thermally enhanced insulated glazing unit glass spacers were employed between the glass and steel.
3. The structural steel plate frame bears on fiberglass-reinforced shims to create a thermally improved connection to the precast concrete wall.

**THERMALLY ENHANCED STEEL** (included) vs **INITIAL STEEL DESIGN** (not included)



Toulooukan Toulooukan Inc.



Therm program 2D heat transfer modeling output.

what's *cool* in steel

# COOL Walk on the Wild Side



Courtesy of Wild Center

**THE WILD CENTER** is a natural history center situated amongst the trees of the Adirondacks in Tupper Lake, N.Y.

By no means a typical museum, the exhibit allows patrons to learn about nature by experiencing it firsthand on the Wild Walk, a series of steel bridges and towers. Visitors enter the first tower from ground level and by the time they make their way to the highest point, they are standing above the trees. The designer, Charles P. Reay, envisioned an experience that blends in with the forest and allows visitors to “see the world the way the wild does.” Each tower was strategically placed to weave into the forest while disturbing as few trees as possible.

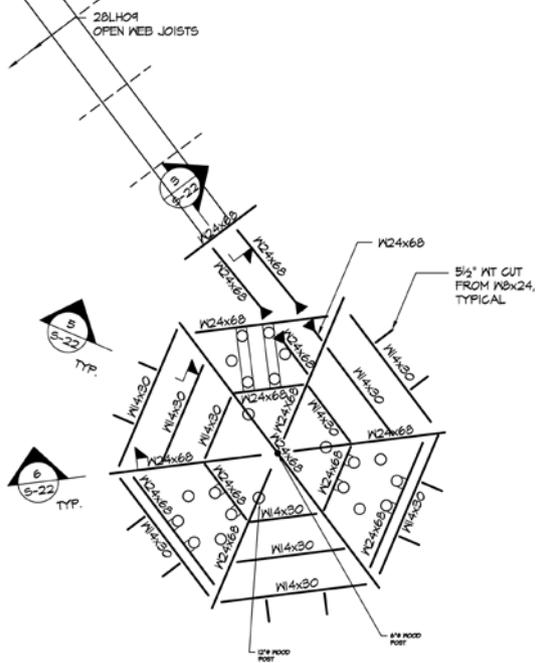
Designed by Linescape Architecture and Silman, the project consists of several elevated platforms supported by teepee-like towers. It also features a large-scale treehouse and spiderweb, an eagle’s nest, three steel-framed swinging bridges and the snag—a dead tree standing four stories high. Each tower structure is built of six weathering steel (ASTM A847) hollow structural sections (HSS) that come to a point approximately 40 ft in the air and comprise a 16-ft diameter circle on the ground. The size and color of these “posts” mimic the trees that surround them. The platform structure consists of wide-flange beams “fish-plated” to the sides of the posts (the beams’ shear tabs are inserted through the walls of the columns) and cantilevered out to form a star-like shape. The beams cantilever

further to support the edge of the walkway bridges that connect each tower. The wider platforms are constructed of several interwoven tower structures, with posts crossing past each other as they reach their final point. At the top of the 42-ft-tall eagle’s nest, visitors find themselves above the tops of the trees and towers alike.

The spiderweb structure is built of eight 24-ft-tall round steel posts with a 35-ft-wide octagonal steel-framed platform above. The center of the platform houses a large spiderweb net tied to schedule 40 HSS that are welded back to the main platform. The top-heavy structure was designed to account for several children jumping on the web at once and the nearly 60-ft walkway bridge that ties in on one side.

The 15-ft-wide snag structure looks identical to an enlarged dead white pine tree, but its skeleton is composed of several wide-flange and HSS posts. The snag internally supports a spiral stair and externally supports the ends of two steel swinging bridges. The post locations were coordinated with the architect to align with the stair treads and sized to resist wind loads as well as lateral loads imposed by the swinging bridges. The slanted roof was designed for the heavy snow of the Adirondack Mountain region.

And then there’s the Ubertwig, a three-story treehouse that boasts three swinging bridges and a walkway bridge. The main structure is built from wood joists and 12-in.-diameter cedar posts, but steel moment frames were introduced at the interface

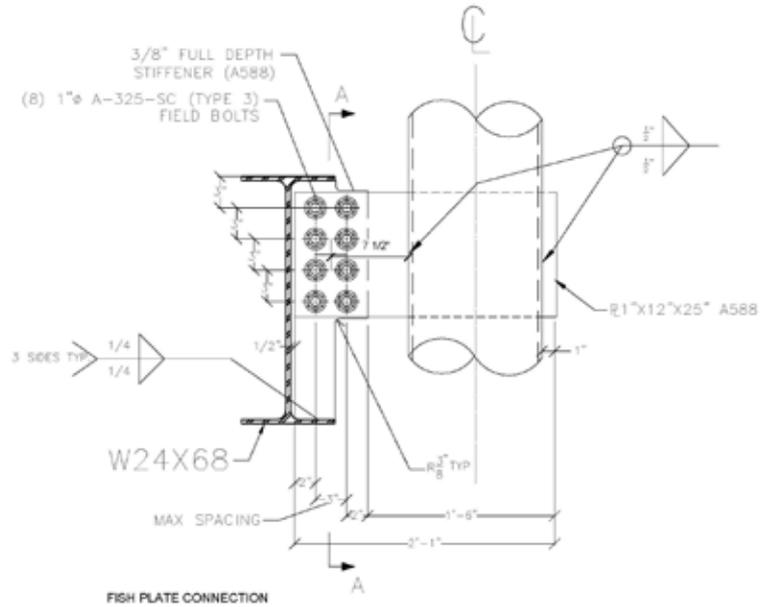


Courtesy of Wild Center

between the bridges and main structure, and specially designed connections of wood to steel posts and beams were developed to meet the connection challenge.

Three swinging bridges add an element of movement to the otherwise stationary trail. The museum wanted to create an experience that feels exciting yet is completely safe. Each bridge has five 3/4-in.-diameter cables running from moment frame to moment frame, strung through upside-down A-shaped WT frames every 5 ft to provide stiffness. The final result is a bridge experience with a bit of bounce—especially with several walkers—but without excessive vibration.

In order to meet the demands of designing the asymmetrical Wild Walk, the structural design team had to think outside the box. The result is a unique structure that allows visitors a new perspective on their natural surroundings.



FISH PLATE CONNECTION



Courtesy of Wild Center



Courtesy of Wild Center

what's *cool* in steel

# COOL Cantilevers

**ONE OF SAN DIEGO ARCHITECT** Norm Applebaum's signature design elements is to "pierce through the sky" with exposed cantilever beams.

And a steel-and-glass home he designed for Linda Starkman does just that. Integrated with a tree-covered knoll at Starkman's 320-acre Fox Hollow Ranch in El Paso de Robles ("the pass of the oaks"), central California's fastest growing wine region, the 4,500-sq.-ft home is covered by a dramatic sloping roof that appears to defy gravity as it floats above expansive clerestory glazing. At 13,000 sq. ft, the roof is more than twice the size of the enclosed living space, with overhangs that provide shading and extend the interior space into the scenic surroundings.

The home's footprint was planned around three ancient multi-trunked oak trees, and the extending steel roof beams were located so as to not disrupt future tree growth. The long cantilevered roof overhangs and floor decks project over the steep hillside and are designed to resist wind uplift forces, which are magnified by the topographic effects of wind speeding up the hillside.

SDSE Structural Engineers designed hundreds of cantilever elements for the house, from roof beams and seismic-resisting columns to serving counters the size of diving boards cantilevering up to 9 ft with zero back span. The roof beams pushed the material limits of steel, with 50-ksi W21×101 and W21×147 members cantilevering up to 50 ft. The bottom flanges of the W21 roof beams are exposed, all exposed connections were welded and ground smooth and dozens of custom steel details were required throughout the project.

The architect and structural engineer worked closely to achieve balanced proportions by minimizing steel beam depth while maximizing cantilever distances. Early in the design, Applebaum built a basswood architectural model of the steel frame over the floor plan. Where it was necessary to add columns or reduce a cantilever beam length, SDSE would tap on the model's cantilever beams to show the architect that certain beams deflected excessively. While not a precise representation of steel beam deflections, it proved a good negotiating tactic.

One of the many design challenges involved calculating the camber required for the cantilevered beams so that, at completion of construction, the exposed wide-flange steel beams would end up straight and level. Complicating this was the fact that many of the cantilevered beams were supported by other cantilevered beams, creating a complex puzzle. Close coordination between SDSE and the detailer, in terms of understanding which beam provided support and which was being carried, resulted in a smooth, efficient erection process with no fit-up problems.

Big Bertha is the name given by the architect to the longest cantilevered roof beam, a W21×147 with a 50-ft cantilever over the steep hillside; the beam is doubly cantilevered, with total length of over 100 ft. With a back span of 33 ft, Bertha's longer 50-ft cantilever end has an upward camber of 6 in. and its shorter 23-ft cantilever end has an upward camber of 1½ in. ➤



John Durant



John Durant



John Duran



Melissa Kroskey



Malissa Koslley



John Curran

what's *cool* in steel

# COOL Cantilevers

An access road had to be constructed on the Fox Hollow Ranch so that trucks and supplies could wind their way around the hillside up to the jobsite. Steel roof beams that exceeded 60 ft were spliced with directly welded moment connections in the field, and the design team worked closely to choose splice locations at points of lower stress that would also maximize fabrication efficiency. The general contractor was challenged with finding space on the constrained hilltop site for staging the longer steel to be field welded before being lifted into place. The erection, performed by Bragg Crane and Rigging (an AISC member and certified erector) was phased and carefully planned to work around the steel beams (over 100 ft in length) that were laid across the hilltop site for field welding. Construction access around the beams was limited until they were lifted up into place.

Steel roof beams are skewed in plan at a 45° angle to the steel columns. Steel columns were limited to a 6-in. dimension to achieve the architectural desire for the edges of the columns to be inset from the skewed flanges of the steel roof beams they support. The substantial 12-in.-wide by 21-in.-deep steel beams are supported by 6-in. steel box columns. The columns are W6x25 shapes with ½-in. plates welded parallel to the web and inset from the flange edges, forming a box-shaped column to provide more stiffness against weak-axis bending due to lateral loads on the cantilevered columns. The exposed steel is protected (and accentuated) by two coats of red oxide primer.

The seismic load resisting system consists of steel columns cantilevering from plywood shear walls, two triangular-shaped concrete masonry block chimneys and structural steel braced frames. All of the walls except the chimney stop at an elevation of 7 ft and have clerestory glazing extending to the underside of the roof. The steel columns cantilever vertically to transfer lateral forces from the plywood roof diaphragm to the shear walls, and custom concealed steel plate connection details were developed for these transfers.

Two steel braced frames are located in the master bedroom wing to resist lateral forces from a long claw-shaped cantilevered roof diaphragm. The roof diaphragm at the master bedroom wing cantilevers horizontally 25 ft beyond the last line of braced frames. This horizontal diaphragm cantilever exceeded the limitations of a plywood diaphragm, and therefore a structural steel tube truss was designed and concealed within the ceiling framing to transmit lateral diaphragm loads. The steel braced frames stop at the 7-ft top-of-wall horizontal datum, and the columns cantilever vertically up to the roof diaphragm.

Steel columns were designed to resist significant uplift forces from the combined effects of seismic overturning, plus uplift forces due to gravity loads at long cantilevers with short back spans. Steel columns are anchored to concrete pedestals supported by concrete spread footings and grade beams and in some areas, the footing sizes were governed by the weight needed to hold down the steel columns.

The designers chose steel for its strength and aesthetics. It was the only material capable of achieving the long cantilevers while minimizing the depth of the structure and enabling clean connection detailing. It was also the key to creating a “wow” factor with the dramatic roof soaring over the glass home.



Melissa Kroskey

what's *cool* in steel

# COOL Zoo



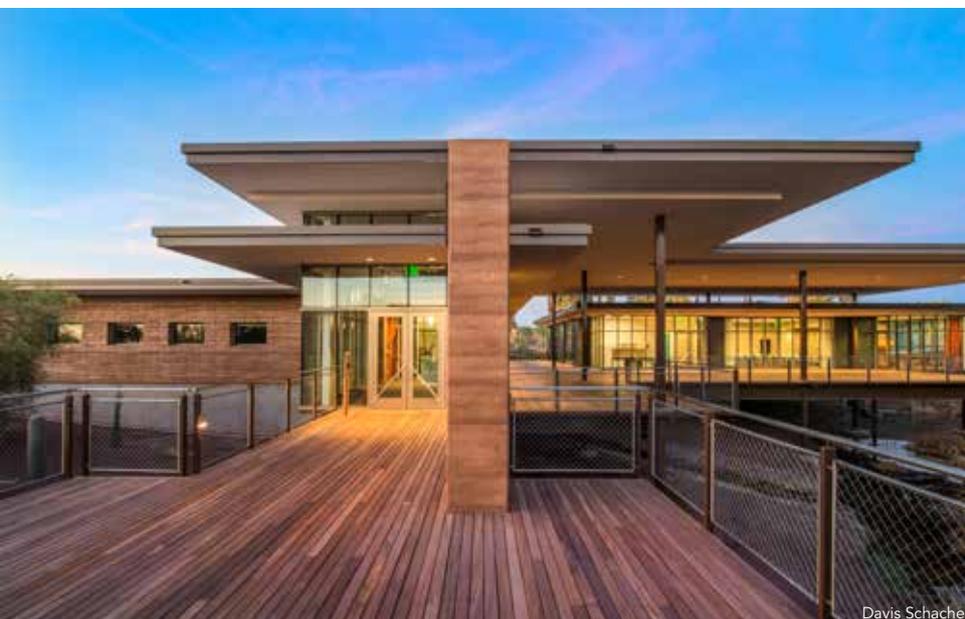
Jim Todd



Jim Todd



Todd Woolsoncroft



Davis Schacher

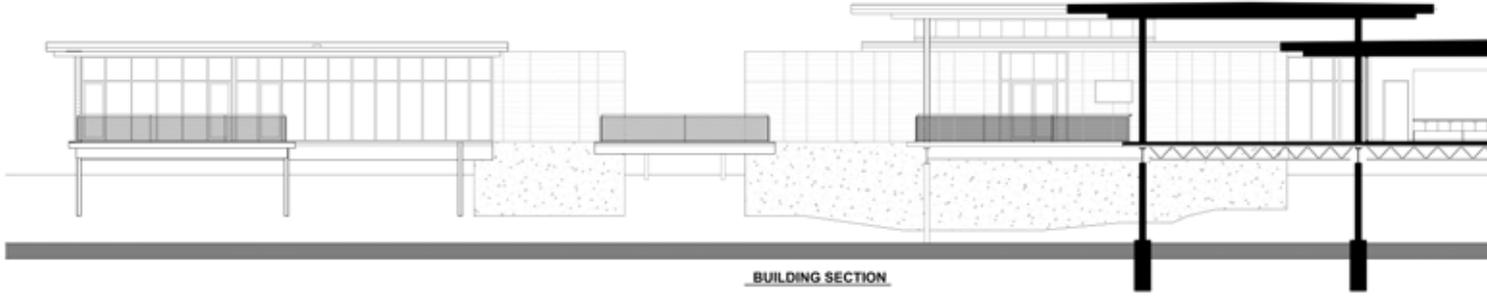
**HOVERING JUST ABOVE** a glistening lake at the Phoenix Zoo sits a new administration facility.

Designed by WDM Architects and Bakkum Noelke Consulting Structural Engineers, the small complex consists of three separate buildings sitting on a single elevated deck and comprising 28,000 sq. ft. Every piece boasts dramatic lines in the rammed earth walls and the tiger-wood deck boards, with the largely horizontal lines being punctuated by vertical exposed steel beams. The roof's deep overhangs are striking against the sky, drawing visitors' eyes up and into the vast blue beyond.

The largest building of the three contains an open office area, conference rooms and offices, and houses the Papago Park ranger's office area. Staff in this building facilitates day-to-day zoo operations. The second-largest building is the executive office building, which includes the zoo executive staff and CEO offices, general offices and a board room. And the third building houses volunteer training and support areas.

The roof, the standout element of the steel-framed project, has a frame comprised of steel beams supporting steel deck assemblies. All roof beams are located within a single plane for each independent roof, which required multiple moment connections to provide the cantilevered roof edges extending beyond the building walls below. Using steel beams in the single roof plane allowed for a slimmer sight line while achieving deep roof overhangs, elements that give the structure its unique silhouette.

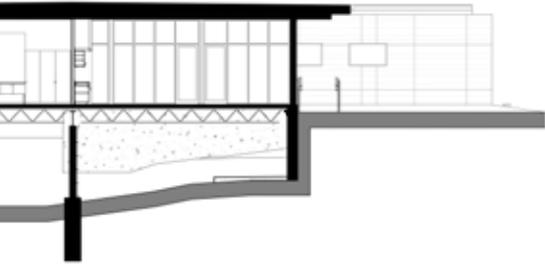
In addition to achieving the design intent, the steel framing also allowed the building's program to be accomplished in this specific location, maximizing the program requirements and strengthening the zoo's mission. Using steel, the structure was able to be elevated roughly 12 ft, 6 in. above the lake, making the site usable for the square footage the program called for. This also allowed the design to have the least amount of impact on the lake, with only four of the complex's 50 total pilings impacting the lake. The natural habitat was largely untouched, allowing the lake's plant and animal life to continue to thrive. ➤



Davis Schacher

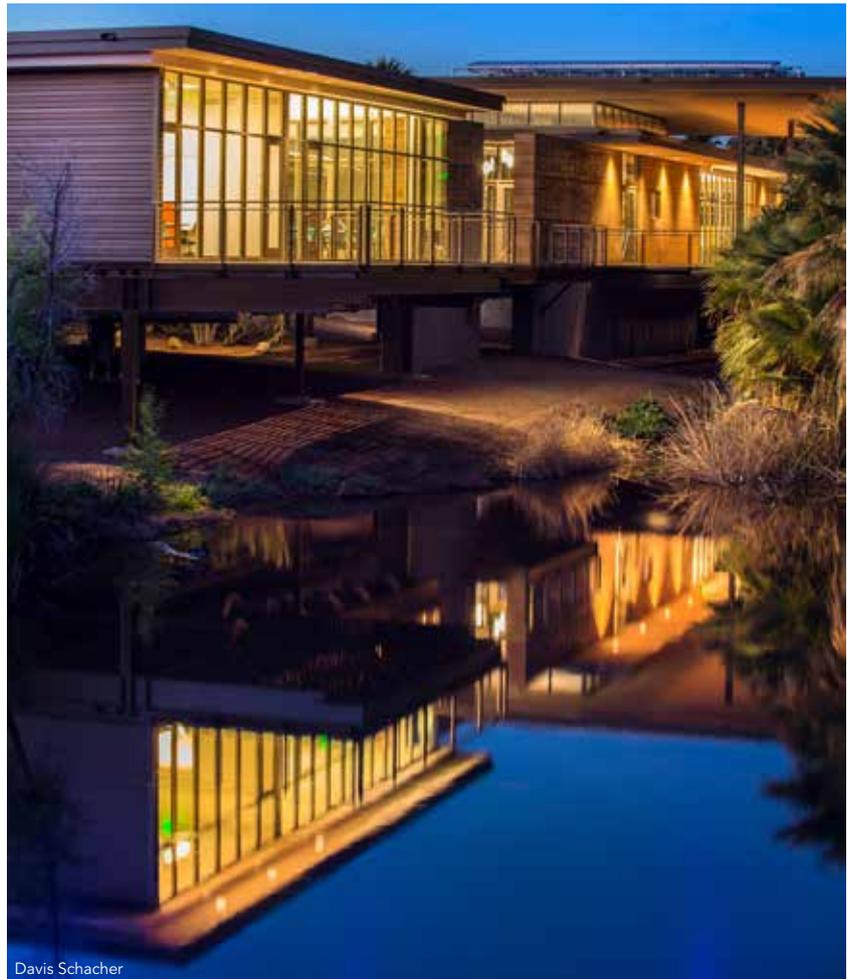


Davis Schacher



The floor framing consists of open-web steel joists and steel beams supporting concrete-over-steel deck at the interior spaces and wood deck framing at the exterior spaces. Perimeter infill walls are a combination of rammed earth, glass and clad stud walls. The lateral force resisting system for the building relies on a combination of steel moment frames, rammed earth walls and diagonally braced steel stud walls. AISC member SNC Engineering, Inc., performed the steel detailing.

It was due to the innovative structural steel design that this building could be where it is and what it is—and be even better than what was needed. A simpler building would have sufficed for staff and volunteer space. But this structure, situated on top of a lake, stands out as an attractive focal point while fitting in with its surroundings. ■



Davis Schacher