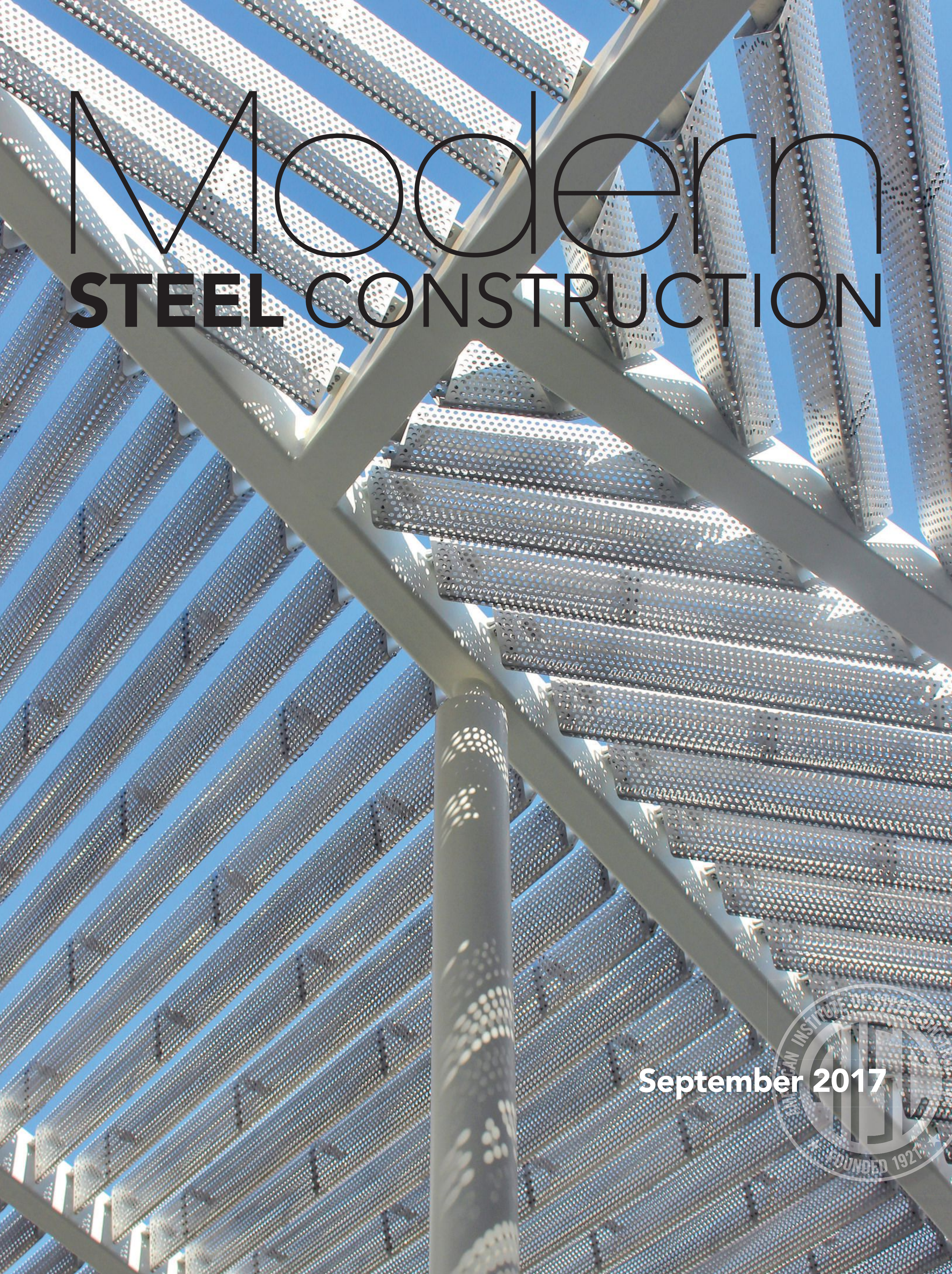


Modern STEEL CONSTRUCTION

September 2017

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
FOUNDED 1921

Above all, ART

BY BRET LIZUNDIA, SE

Precision structural design meets inspired architecture to create an art museum topped with a complex canopy that is, itself, an inspiring steel sculpture.

BCJ


BCJ

▲ The museum's signature steel canopy is roughly 50,000 sq. ft and covers all three buildings and most of the remaining site.

EVERY WORK OF ART starts with an inspiration.

The architects of the new Jan Shrem and Maria Manetti Shrem Museum of Art at the University of California, Davis, wanted the building itself to be a work of art and drew their inspiration from the "quilted agrarian landscape" that stretches beyond the site on the opposite side of Interstate 80 from campus. The idea was to create a building that "inherits the idea of diverse landscapes, textures and colors stitched together," one that is "neither isolated nor exclusive but open and permeable—not a static shrine but a constantly evolving public event," according to Florian Idenburg, founding partner of SO–IL.

Designed by associated architects SO–IL and Bohlin Cywinski Jackson (BCJ) and structural engineer Rutherford + Chekene (R+C), the museum program includes a set of irregularly shaped one-story and two-story buildings (referred to as pavilions) providing gallery, studio, community, administrative and service spaces—all linked together by a low roof and an undulating 50,000-sq.-ft steel canopy.

This signature canopy covers the buildings and the majority of the remaining site. The varying angles and porosity of the canopy infill members filter and reflect sunlight, creating an experience that changes throughout the day and from season to season. The canopy extends the building and the possibilities for making and enjoying art. Intimate and yet expansive, flexible and inviting, the canopy was designed as a focal point for both contemplation and collaboration.

Skews and Slopes

Structural steel was the best material to meet the architects' vision for the canopy as well as the rest of the facility, due to the pavilion's irregular shapes, long spans, thin, elegant aesthetic and the desire to marry the interior and exterior structural elements. The three pavilions, which total 30,000 sq. ft, consist of a main gallery building with high-bay and long-span conditions; a one-story building that includes classroom and public meeting space, studio arts space and function areas; and a two-story wing (with a one-story section) with restrooms, offices, the lobby and maintenance and mechanical space.

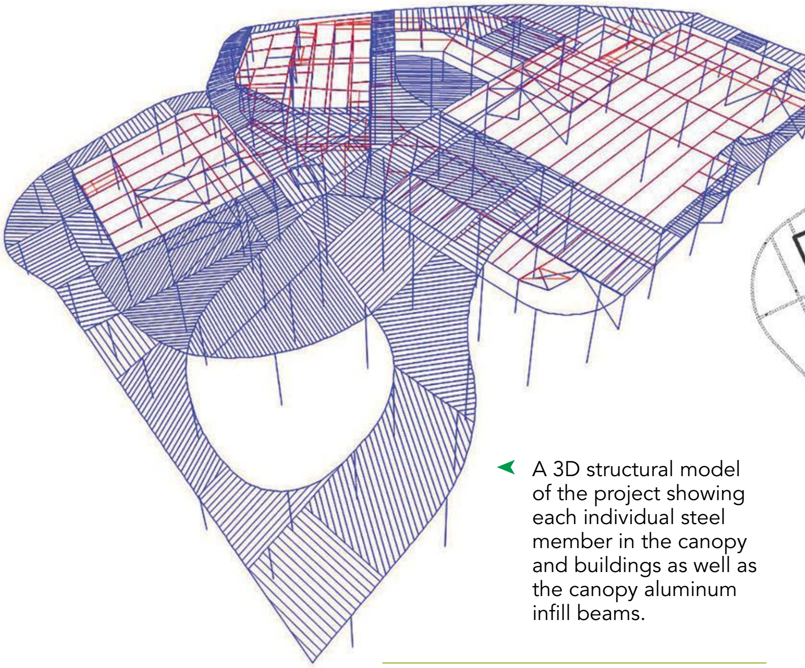
The pavilions use composite deck diaphragms supported by steel beams and girders, with steel columns bearing on spread footings and grade beams. Steel framing efficiently supports the long-span roofs over the large galleries and addresses the complicated skewed conditions, sloping and intersecting roofs and various cantilevered regions, the longest of these being 28 ft, 6 in. Buckling-restrained braced frames (BRBFs) serve as the lateral force-resisting system in the pavilions, as the museum is in a high-seismic region. While concrete shear walls were also

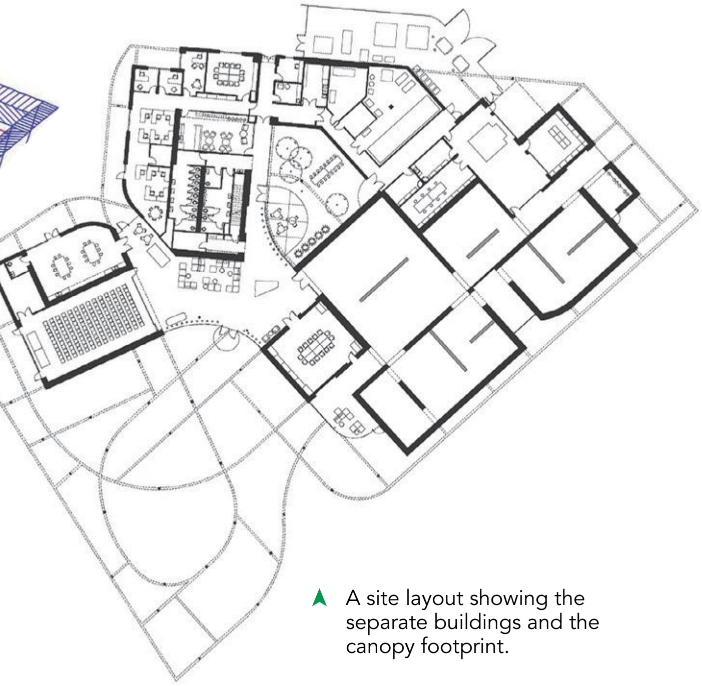
◀ Undulating canopy framing prior to installation of the infill beams.

Bret Lizundia (blizundia@ruthchek.com) is a principal with Rutherford + Chekene in San Francisco.


R+C

The canopy extends out to the corner of the site and is integrated with the landscaping.

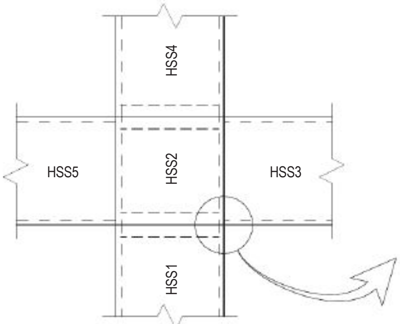

A 3D structural model of the project showing each individual steel member in the canopy and buildings as well as the canopy aluminum infill beams.


A site layout showing the separate buildings and the canopy footprint.

considered, the steel bracing system ended up being the most prudent choice due to the irregular geometry of the buildings and the ability to locate the braces where they could accommodate the open, flexible program and still effectively provide a balanced lateral force-resisting layout in each pavilion.

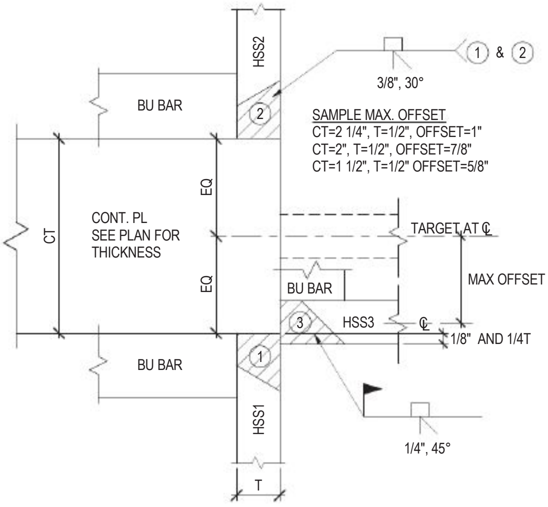
For the exterior, a lightweight metal and curtain wall cladding system was initially considered, but precast panels with a ribbed undulating surface were eventually selected and were carefully detailed to accommodate the inter-story drift of the braced frames. The canopy is constructed from HSS14×10 beams and girders, rolled into complex curves, that support varying arrays and patterns of more than 900 perforated aluminum triangular beams. In turn, the canopy beams and girders are supported by round HSS and pipes of varying diameters ranging in height from 15 ft to 35 ft. The canopy columns are each founded on a concrete drilled pier, creating a “flag pole” system of cantilever columns. The canopy is tied to the building pavilions, so lateral forces are shared by the cantilever columns and the BRBFs, and the canopy girders function as seismic collectors.

➤ To address gravity moments from offset columns, torsional demands from members curving in plan and large wind and seismic demands, the HSS-to-HSS joints are all made with moment connections. The connection details use several different strategies and sizes of continuity and through plates to provide increased tolerance where needed.

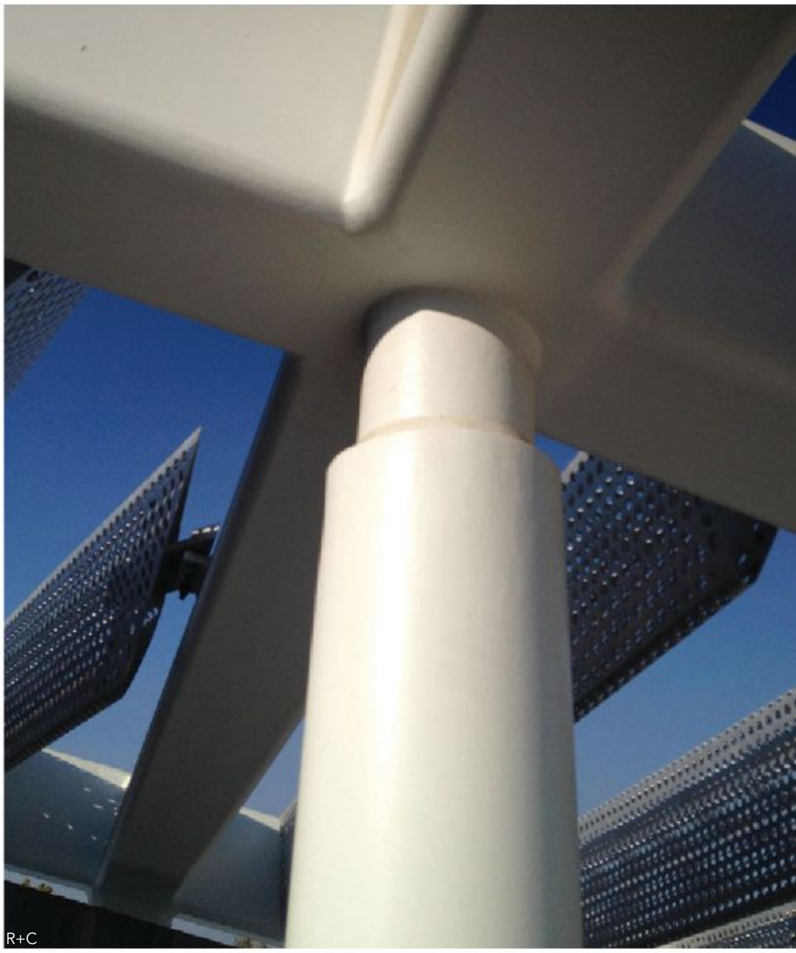


PLAN
1 1/2"=1'-0"

APPROACH WHERE UP TO 1" PLAN OFFSET FOR HSS3 & HSS5 IS REQUESTED AND ALIGNMENT W/ CONT. PLATE IS STRUCTURALLY REQUIRED



DETAIL
1"=1"



▲ The canopy includes more than 900 perforated aluminum triangular beams.

➤ The canopy beams and girders are supported by round HSS and pipes of varying diameters ranging from 15 ft to 35 ft tall.

The team used RAM Structural System for gravity design of the composite framing of the buildings and a SAP 2000 model that included both the buildings and the canopy for dynamic analyses of wind and seismic loading. Detailed finite element analysis studies of selected joints were also performed to optimize member and connection sizes. A wind consultant provided advice to address unusual loading conditions at the canopy, thanks to the use of triangular long-span perforated infill beams that had a number of different architectural patterns and spacing distances. The consultant also analyzed the site's exposure factor, as the area to the south is wide-open farmland and the area to the north is tree-filled, resulting in different wind loads from different directions.

Inspired Innovation

The building's design came with multiple structural challenges requiring innovative solutions, including the following.

Torsional balance: The pavilions and canopies all have different heights, geometries, masses and dynamic characteristics, and yet they are programmatically and structurally linked. Careful location and sizing of the BRBFs and cantilever columns was necessary to achieve torsional balance, minimize the loads transferred between pavilions and reduce drift at the canopy edges to acceptable levels. Because the northwest end of the canopy is highly eccentric to the building, rigorous analytical effort was needed to prevent it from becoming "the tail wagging the dog." Column sizes and the elevations of the base of the columns were varied to tune the lateral system for optimal performance in wind and seismic conditions.

Sloped roofs and connecting diaphragms: The pavilion roofs all have different geometries, and there are numerous setbacks, mezzanines and cantilever conditions. In some cases, the high roofs slope steeply enough to connect to the low roofs, creating complicated inter-story drift situations across the footprint, which were addressed with special detailing.

Efficient bending of HSS: Initial architectural canopy forms included a variety of double curvature bends of different radii in the HSS girders. By working with fabricator Olson Steel and bender-roller Albina Co., Inc., to select optimal joint locations, complicated curves were reduced, bending was simplified and straight elements were used where curves were not aesthetically essential, saving significant costs while achieving the same desired architectural form.

The canopy included members that were to be bent the "easy way" in the 10-in. direction of the HSS14×10, the "hard way" in the 14-in. direction and even in the off-axis direction. Part of the value engineering challenge was determining which members would require bending in multiple planes (both the easy way and the hard way) as opposed to standard, less expensive bending in one plane and in determining where to split longer members to minimize the extent of bending while still achieving the desired shape of the canopy. Of the 43 members to be bent, 26 required multi-plane bending. Fortunately, some of the steel bent in multiple planes was rotated off-axis only a slight amount, and the radius was large enough that it could be cold bent, which is a faster process than hot bending.

Complicated geometry: Special details were developed for skewed and sloped moment connections at wide-flange columns in the building and where canopy tubes come together at highly acute angles. And in order to create more intriguing canopy forms, the canopy columns were typically offset from girder intersections. The top of the column is narrowed to a smaller section to provide a more elegant connection to the underside of the girder, creating partially restrained conditions.


R+C

▲ A full-size mockup including the precast cladding, glazing and canopy was built.

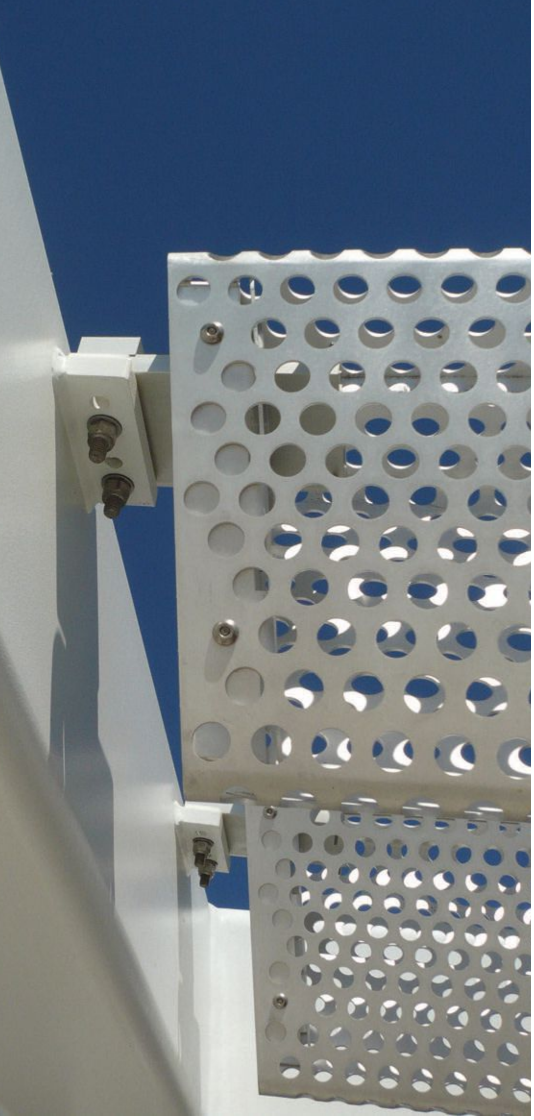
▼ The pavilion roofs all have different geometries, and there are numerous setbacks, mezzanines and cantilever conditions.


R+C


UC Davis

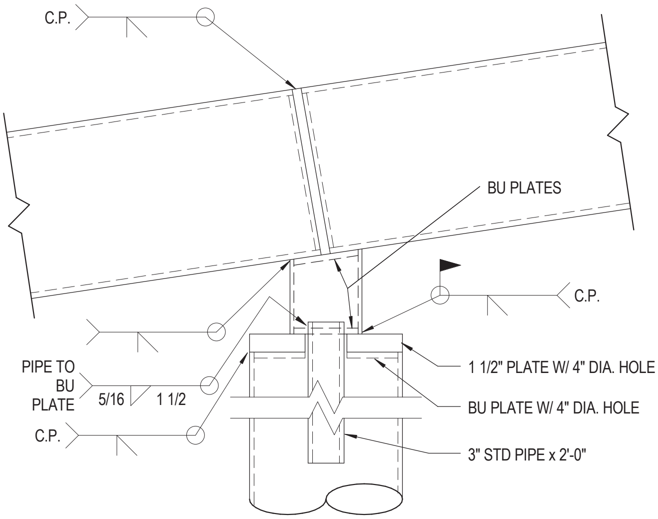
◄ Connections between the aluminum canopy infill beams and HSS framing.

▼ The steel braces were located where they could accommodate the open, flexible program and still effectively provide a balanced lateral force-resisting layout in each pavilion.



R+C

R+C



▲ A connection between a supporting column and a canopy element.

◄ Special details were developed for skewed and sloped moment connections at wide-flange columns in the buildings.

The design and erection team developed project-specific welding techniques and fit-up procedures.

Olson's in-house detailers reviewed architectural models, submitted in Rhino, to determine what would be constructable in the real world. The original Rhino models consisted of curves that wouldn't be practical to fabricate or erect, and the detailing team provided solutions that added constructability.

Project-specific AESS: The canopy steel framing is all architecturally exposed structural steel (AESS). Specifications defined two levels of AESS such that tighter shop and field tolerances and higher-quality member surface and weld preparation and finishes were targeted at the critical locations for fit-up and aesthetic importance, with less stringent and more economical requirements being implemented at less-sensitive locations.

The high-profile and highly visible steel required high-precision surface preparation and high-performance coatings. Surface preparation was performed to SSPC-SP6/NACE 3 Commercial Blast Cleaning requirements, and the various coatings applied were as follows:

- Shop-applied primer: Tnemec Series 90-97, Zinc Rich Primer at 2.5 to 3.5 mils dry film thickness (DFT)
- Primer (field-applied touch-up): Tnemec Typoxy Series 27WB, water-based epoxy field tie-coat at 4.0 to 6.0 mils DFT
- Intermediate coat: Tnemec UVX Series 750, Polyfunctional Hybrid Urethane applied at 2.5 to 4.0 mils DFT
- Top coat: Tnemec Fluoronar Series 1072V, Thermoset Solution Fluoropolymer applied at 2.0 to 3.0 mils DFT

Joints and tolerances: To address gravity moments from offset columns, torsional demands from members curving in plan as well as large wind and seismic demands, the HSS-to-HSS joints are all made with moment connections. The connection details use several different strategies and sizes of continuity and through plates to provide increased tolerance where it was needed.

Mockup: A full-size mockup including the precast cladding, glazing and canopy was built. While mockups typically serve as visual models for the architect, especially for projects involving AESS, the robust mockup for the Manetti Shrem Museum was equally beneficial from a structural and constructability perspective, as it incorporated the numerous curves and tricky angles desired by the architect; a simpler model would not have been as informative. The HSS joints in the mockup were put through nondestructive testing with the inspector, who would also check the future production welds.

Project-specific welding techniques and fit-up procedures were developed between the erector (Olson) and R+C to account for observed joint tolerances as well as to minimize weld distortion. The canopy incorporated more than 900 infill beams attached with more than 1,800 clips. Thanks in part to the mockup, every single one fit in the field.

Infill beams: R+C and the infill beam engineer, Front, Inc., worked together to detail the infill beams with a fixed connection at one end and a special connection at the other end. The latter remains fixed for low-level loads but slips at a defined fuse level at high wind and seismic loads caused by out-of-phase deflections between the supporting HSS members at each end.

Karl Backus, design principal with BCJ, described the museum's design as having grown out of an ideas-driven, interdisciplinary collaboration of architects, engineers, fabricators and builders. "We strove to create a diverse spatial experience that encourages interaction and learning underneath the canopy structure," he said. "Given the complexity of programmatic uses, site relationships and construction technologies, the teamwork has been essential and uniquely fruitful." ■

Owner
University of California, Davis

General Contractor
Whiting-Turner Contracting Company, Folsom, Calif.

Associated Architects
SO–IL, Brooklyn, New York
Bohlin Cywinski Jackson, San Francisco

Structural Engineer
Rutherford + Chekene, San Francisco

Canopy Infill Beam Engineer
Front, Inc., Brooklyn

Steel Team

Fabricator, Erector and Detailer
Olson Steel, San Leandro, Calif.

Braced Frames
Corebrace, LLC, West Jordan, Utah

Bender-Roller
Albina Co, Inc., Tualatin, Ore.