AISC 2005 EAE AWARDS

ENGINEERING AWARDS OF EXCELLENCE

The Engineering Awards of Excellence are presented annually by AISC to recognize engineering excellence and innovation in steel-framed buildings. There are four categories based on project cost: less than $10 million; $10 million and greater but less than $25 million; $25 million and greater but less than $100 million; and $100 million and greater.

More than one project can be submitted by the same firm and each submittal is considered a separate entry.

ELIGIBILITY

- A significant part of the framing system must be steel wide-flange structural shapes or hollow structural sections.
- Building construction must have been completed between January 1, 2002 and December 31, 2004.
- Projects must be located in the U.S., Canada, or Mexico.
- Both new buildings and renovations (major retrofit, expansion, or rehabilitation) projects are eligible.

JUDGING CRITERIA

- Creative solutions to the project's program requirements
- Application of innovative design approaches in areas such as connections, gravity systems, lateral load resisting systems, fire protection, and blast.
- Use of innovative construction methods such as EDI, design-build, or advanced computer modeling
- Significance of engineering achievement and elegance of design

2005 JURY

Benjamin Baer, P.E., S.E.
Vice President, Ruben J. Baer & Associates Ltd., Skokie, IL

Benjamin is the second-generation head of Baer Associates Engineers, Ltd., a structural engineering firm in suburban Chicago, founded by his father 50 years ago. Ben is a graduate of the Illinois Institute of Technology with a BS in Civil Engineering, a licensed Professional Engineer in seven states, and a licensed Structural Engineer in Illinois. He is an active member of the Structural Engineers Association of Illinois (SEAOI), the National Council of Structural Engineers Associations, and the Structural Engineers Foundation. He is also a member of the Structural Engineering Licensing Board for the State of Illinois.

Ronald F. Middlebrook, S.E.
Principal, Middlebrook + Louie Structural Engineers, San Francisco

During most of the 1970s, Ron worked with the pioneering A/E/C firm of Caudill Rowlett Scott, managing the structural engineering department at their home office in Houston. Later he served as Director of Technology at CRS/New York, where he oversaw engineering design and production, as well as architectural production. Ron spent 18 years with the Los Angeles-based Martin Associates Group. He played a leadership role in the Group's Washington, DC office, before heading to San Francisco in 1983 to head their Bay Area office. In 1994, the office became Middlebrook + Louie. Ron is a past director of the Structural Engineers Association of California (SEAOC), and a past president of the organization's northern body (SEAONC).

Larry E. Whaley, P.E.
President, Haynes Whaley Associates, Houston

Larry is one of the founding members of Haynes Whaley Associates. He directs the firm's administrative and marketing activities, and leads it in striving for creativity, sound engineering, and team collaboration. Larry's education includes a Master of Science in Engineering, Rice University, 1971 and a Bachelor of Science in Civil Engineering with Highest Distinction from the University of Kentucky in 1968. He has over 30 years of experience in the planning and design of building structural systems.

2005 AWARD WINNERS

LESS THAN $10M

NATIONAL WINNER
Desert Bloom Porte Cochere—Cabazon, CA

MERIT AWARD
Davis Conference Center—Layton, UT

$10M OR GREATER, BUT LESS THAN $25M

NATIONAL WINNER
The University of Arizona Large Binocular Telescope Enclosure—Mount Graham, AZ

MERIT AWARD
St. Martin's Episcopal Church—Houston

MERIT AWARD
Robert Hoag Rawlings Public Library—Pueblo, CO

$25M OR GREATER, BUT LESS THAN $100M

NATIONAL WINNER
William J. Clinton Presidential Center Museum Building—Little Rock, AR

MERIT AWARD
Jay Pritzker Pavilion—Chicago

MERIT AWARD
University of Chicago Graduate School of Business—Chicago

$100M OR GREATER

NATIONAL WINNER
Seattle Central Library—Seattle

MERIT AWARD
The Adaptive Reuse of Soldier Field—Chicago

MERIT AWARD
St. Luke's Hospital Cardiac Center and Patient Tower—Milwaukee

$100M OR GREATER

NATIONAL WINNER

Seattle Central Library

Seattle

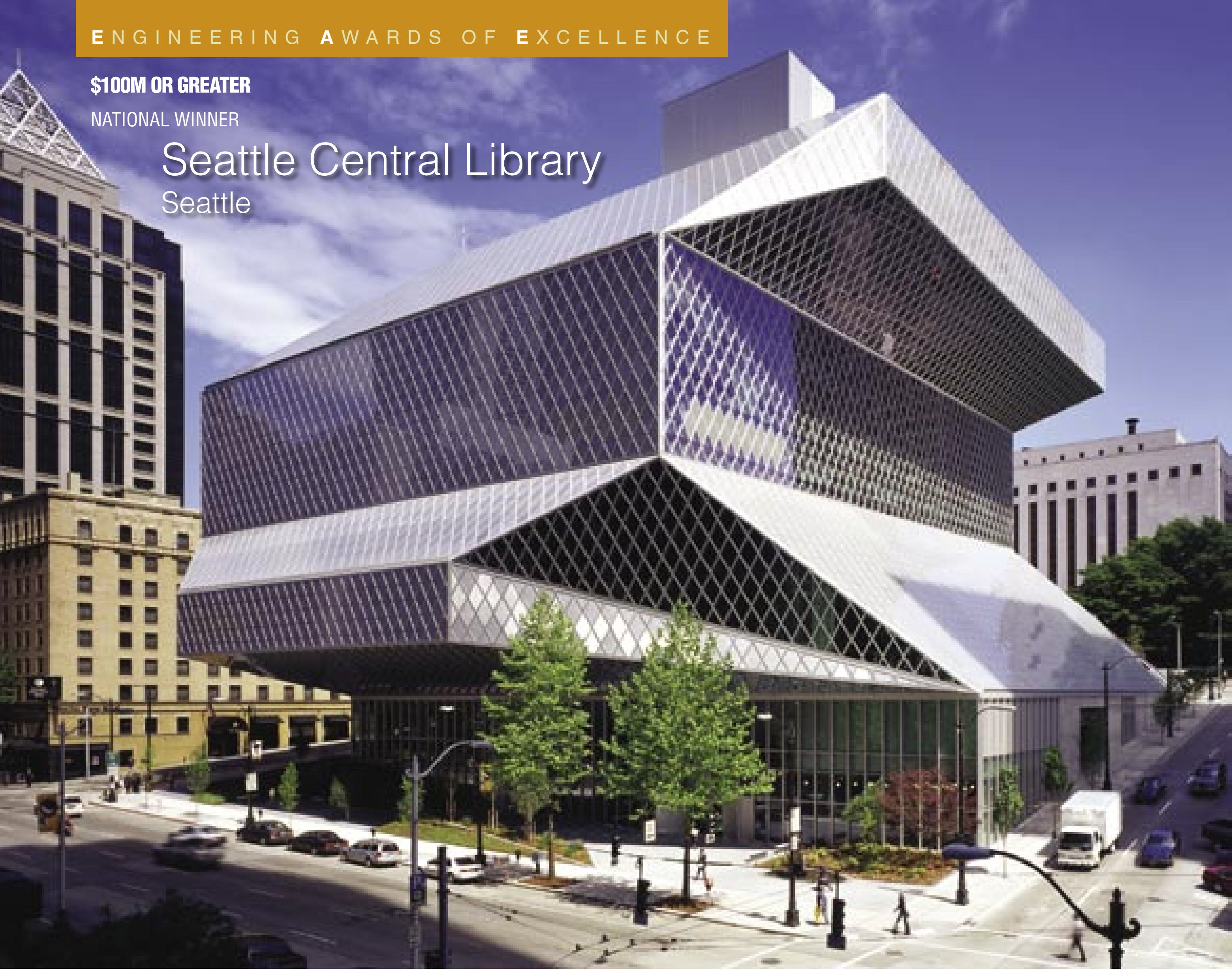


Photo by Lara Swimmer.

JUROR COMMENT

“Very inventive solutions in structural steel to meet complex structural challenges.”

The Seattle Central Library is an elegant study in form following function. The project’s architects organized the library’s programmatic requirements into five independent, yet connected, “platforms” which were vertically stacked, offset to maximize surrounding views, and enclosed in a steel-and-glass wrapper. This transparent package was delivered to the structural engineers with a demanding set of rules: use no columns in the corners, no vertical columns, and as few columns as possible. In essence, the project’s success depended on making a 12-story, all-glass building — in UBC Seismic Zone 3 — appear to “float” without support.

MKA’s solution (working with Arup during schematics) was two separate, layered structural systems. In the first system, multi-story-deep perimeter platform trusses carry the building’s gravity loads. The trusses are supported by carefully positioned sloping columns that maximize counterbalancing opportunities, with platforms cantilevering as much as 52’. The second system, the diamond-shaped steel grid, forms the building’s exoskeleton. The steel grid provides the building’s lateral system, interconnects the platform trusses, serves as the interior architectural finish, and supports the building’s glass curtain wall.

Specially designed slip connections laterally join the steel grid to the platform trusses. The connections merge the two structural systems while preventing the transfer of gravity loads into the grid. This kept the grid slender, eliminated the need for fireproofing of the grid steel, and, most importantly, retained the desired aesthetics. Full-scale mockups of the connections were built and tested, and the connections were fully modeled in 3-D.

Photo courtesy Magnusson Klemencic Associates.

Structural Engineers

Magnusson Klemencic Associates, Seattle

Arup, Los Angeles, London, San Francisco, and New York offices (design development and schematics)

Engineering Software

SAP2000

Architects

Office for Metropolitan Architecture (OMA), Rotterdam, the Netherlands

LMN Architects, Seattle

Detailer

BDS Steel Detailers, Mesa, AZ, AISC member, NISD member

Action Steel Detailing, Inc., Mesa, AZ, AISC member, NISD member

Detailing Software

Xsteel

Fabricator

Canron Western Constructors, Inc., Portland, OR, AISC member

General Contractor

Hoffman Construction Company, Portland, OR

Photo by Michael Dickter, Magnusson Klemencic Associates.

Graphic courtesy Magnusson Klemencic Associates.

The exoskeleton was designed so that a common grid steel member size (W12×22) could be used throughout the structure. Diamond shape and size were optimized at 4' per side and 7' high based on plate glass availability, most efficient fabrication, and desire to eliminate the need for secondary mullions. The common size also facilitated prefabrication of the structural steel grid in "ladders" up to 85' tall, greatly simplifying construction.

Three solutions were developed for areas within the grid requiring reinforcement:

- "Strongbacking" the steel grid with an additional layer of grid in a shape reflecting the exact pattern and location of stress demands
- Sparingly inserting angled transverse "intervention" columns to carry loads most directly from points of maximum stress to the nearest support column
- Utilizing sloping gravity columns in line with the plane of the seismic grid.

Inside the 412,000-sq. ft building, a structural "book spiral" provides a continuous floor for the library's nonfiction collection. The spiral required the creation of a gradually sloping switchback ramp system spanning four floors, accessible to all ages and abilities, able to support heavy bookracks, supported by minimal columns, and economically constructed. Other unusual features include a nine-story atrium through the center of the building, a meeting level with tomato-red curving walls, and a children's area with playfully sloping columns.

At $273 per sq. ft, the new library was built for significantly less than most recent main city libraries. Designed for function and aesthetics, the building also incorporates many sustainable elements. The Seattle Central Library applied for and received "Silver" certification from the U.S. Green Building Council (USGBC), becoming one of the largest buildings to receive a Leadership in Energy and Environmental Design (LEED) certification.

While the project's design and engineering achieved notable reductions in cost, they also helped lead to one significant increase—library usership. Circulation of materials is up 50%, the number of library cards issued has increased 500%, and attendance is 50% higher than anticipated for the first year. ★

Adaptive Reuse of Soldier Field

Chicago

$100M OR GREATER

MERIT AWARD

Photo courtesy Thornton-Tomasetti Group.

Home to the Chicago Bears, Soldier Field is the oldest stadium in the National Football League. Because it had crumbling infrastructure, outdated facilities, and no club seating, the Bears decided to redevelop the stadium. However, with only 600' between the existing colonnades, it fell more than 100' short of accommodating today's conventional football stadium.

The architectural solution was an asymmetrical design with general admission seats on one side of the stadium and stacked luxury suites atop two cantilevered club decks on the other. That configuration, a first in NFL stadiums, saved just enough space to fit a 61,500-seat stadium inside the colonnades.

Completing the design and translating it into a finished product within the required time frame raised the degree

Structural Engineer
Thornton-Tomasetti Group, Chicago

Engineering Software
SAP2000
Ramsteel
AutoCAD

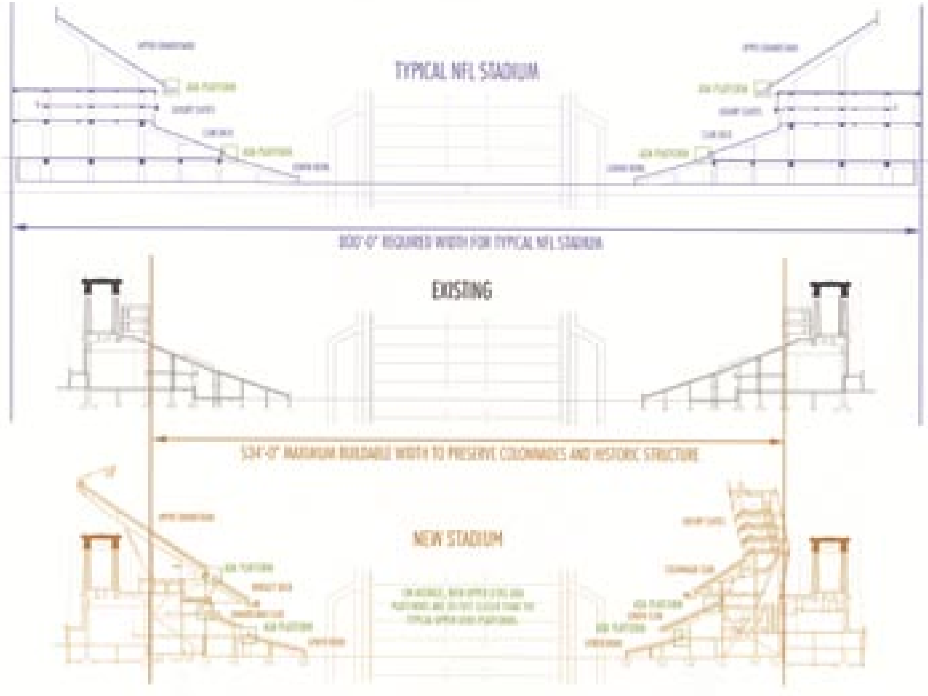
Owner
Chicago Park District—Department of Planning & Development

Architects
Lohan Caprile Goettsch Architects, Chicago
Wood + Zapata, New York

Fabricator
Hirschfeld Steel Company, Inc., Irving, TX, AISC member

Erector
Danny's Construction Company, Inc., Gary, IN, AISC member, NEA member

General Contractors
Turner Construction Co., Chicago
Barton Malow Co., Southfield, MI
Kenny Construction Co., Wheeling, IL



Graphic courtesy Lohan Caprile Goettsch Architects and Wood + Zapata.

of engineering difficulty considerably. The Soldier Field project schedule was 20 months, with less than one month to demolish the existing grandstands.

While the old stadium rested on 10,000 timber piles driven through landfill to an average depth of 62', supporting the new stadium required 2,000 H piles driven 90' to 100' down to bedrock.

Stadium seats are supported on precast concrete risers. The risers span between and are supported by main structural steel rakers that are supported at 40' centers. The rakers supporting the upper grandstand cantilever 60' over the historic colonnades, one of the longest such cantilevers supporting crowds. To keep this seating at a comfortable elevation and distance from the field, yet avoid touching the existing west colonnade, a tapered, built-up plate girder was designed that is approximately 7' at its maximum depth.

The structure of the suites were tilted 14° toward the field, bringing the upper levels of seats closer to the field, thereby providing better sightlines. Two massive video boards, 84' long by 23' high, attach to cantilevered steel trusses extending 100' in space over the end zones.

Many of these breakthroughs were made possible by the stadium's 13,000-ton structural steel frame, which provided great design flexibility. However, the steel frame of the upper grandstand cantilever presented another challenge—maintaining spectator comfort amidst synchronous crowd movements of fans or concertgoers. Because a bare steel and concrete structure has little natural damping to diminish vibrations, a crowd moving at the structure's natural frequency could create vibrations that were noticeable to spectators. A dynamic analysis showed that while structural stability was not an issue, vibration and acceleration in a packed stadium could reach intensities uncomfortable to spectators in the grandstand. The typical solution of adding more columns was impossible because of the colonnades below the cantilever.

To provide the needed vibration control, the engineers incorporated 21 tuned mass dampers (TMDs), located at the tips of the cantilever of the grandstand. The TMDs, about 20 tons each, comprise a concrete mass supported on air springs, tunable steel springs, and a tunable viscous damper connected to the structural frame. Sixty-four accelerometers were attached to the grandstand to monitor its movement. When crowd movement causes the structure to vibrate and the TMDs are tuned to vibrate at the same frequency, the two structures move out of phase, dissipating energy and vibrations.

Finite-element modeling software was used to model the structure and the crowd's forcing function on it, and to determine the placement of the TMDs. To confirm the theoretical results of the modeling, a custom "Vibration Shaker" was attached to various locations on the grandstand. The shaker operated by rotating two sets of weights in opposite directions to induce a measurable vibration into the structure. This test confirmed the frequencies at which resonance would occur and assisted in tuning the TMDs. With the TMDs operating in place, the accelerations remain within the limits for spectator comfort.

Read more about Soldier Field in "Field Goals" in the July 2004 issue of *Modern Steel Construction*, available online at www.modernsteel.com. ★

$100M OR GREATER

MERIT AWARD

St. Luke's Hospital Cardiac Center and Patient Tower

Milwaukee

Photo by David Anderson.

The Cardiac Center and Patient Tower, a 430,000 sq. ft, $187 million addition to St. Luke's Medical Center in Milwaukee, has been dubbed "the hospital on stilts." With the first of eight floors beginning seven stories up, it straddles a multi-level parking garage and connects with the existing hospital. The project's major challenge was erecting the 12-story steel superstructure over and through an existing parking garage that remained operational.

By significantly widening the space between columns and preventing column contact with the garage, the design supports the hospital above and allows for uninterrupted traffic flow in the garage below. Each column is encased by a .5"-thick steel jacket. The column jacket serves a two-fold purpose: one, as a stay-in-place form, and two, as protection from vehicular impact or explosion. A total of 33 columns support the new structure, 14 of which penetrate the parking structure and are completely isolated from it, preventing the transference of vehicular vibrations to the patient tower above.

To perform the column work, drilled piers and 85'-tall, unbraced columns were placed from the roof of the parking garage by a 65-ton drill rig. The rig drilled the piers and placed the columns while traffic moved safely through the garage.

Above grade, the majority of the new structure is supported by 32'-deep steel trusses which bridge the west portion of the parking structure, supporting the steel framing above. Due to the long required reach of both tower cranes, the maximum pick at longest reach was nine tons, thereby limiting the weight of any single truss piece.

Construction of a nuclear medicine addition directly below the west half of the parking structure required the patient tower to clear span 130' over half the parking structure. In order to best use the space between trusses, the mechanical level was placed on this first supported level. The four large mechanical units used to serve this addition are 28'-tall, which set the truss depth at 32'. A mezzanine floor was added to a portion of this level, requiring horizontal framing at the truss's mid-depth. A K-truss configuration was used to reduce the weight of individual chord and web members, allowing

Structural Engineer
Graef, Anhalt, Schloemer & Associates, Inc., Milwaukee

Engineering Software
RAM Structural
Visual Analysis

Owner
St. Luke's Medical Center, Milwaukee

Architect
Kahler Slater Architects, Milwaukee

Detailer
Pacific Drafting, Inc., Carson, CA, AISC member, NISD member

Detailing Software
CDS Asteel

Fabricator
Merrill Iron & Steel, Inc., Schofield, WI, AISC member

Erector
AREA Erectors, Inc., Rockford, IL, NEA member

General Contractor
Oscar J. Boldt Construction Co., Waukesha, WI

the members to comply within the tower crane's maximum load capacity.

W14 members up to W14x730 were used for chords (65 ksi) and webs (50 ksi). Members were oriented with flanges parallel to the truss plane to reduce the weak axis unbraced compression length to half the truss depth. This also allowed the use of both flanges for connections to double gusset plates. Analysis of the trusses considered continuity and redundancy in the extent of a catastrophic load such as an explosion or fire in the parking garage below. Resulting bar forces in chords were up to 3,000 kips. Connection plates were up to 2" thick, 8' x 10' in size and required over 300, 1"-diameter A490X bolts. To fabricate the truss members and gusset plates, software that integrated shop drawing layout dimensions to automated fabricating machines was used, significantly minimizing field fit-up problems.

In the erection of the trusses, a series of 7'-deep temporary trusses were used to support the bottom chord off the new columns and parking structure. The trusses were first erected two in tandem to provide stability for the webs and top chords. Once a truss was stable, the temporary truss was removed, re-fitted for adjacent spans, and re-used. The trusses were provided on four parallel column lines about 40' apart. The top of the trusses formed a rectangular tabletop. This provided a stable working platform for erection of the eight hospital floors above.

Above the truss system, the configuration of the patient rooms is rectangular with a curved, concave exterior wall. The resulting column layout requires a significant number of transfer beams as well as a number of sharply skewed connections.

The seventh floor of the superstructure, which is supported off the top chord of the trusses, houses the cardiovascular operating rooms. This use requires maximum isolation from vibration. Because the mechanical floor is directly below the operating room floor, all mechanical ducts, pipes, conduits, and other components that could transmit vibration could not be hung directly from the steel supporting the floor. A system of isolated HSS columns supporting an additional framework of beams supports this equipment independently. Vibration modeling done before and testing done after completion of the structure indicated that vibration isolation efforts were successful. ★

$25M OR GREATER, BUT LESS THAN $100M

NATIONAL WINNER

William J. Clinton Presidential Center Museum Building

Little Rock, AR

Photo courtesy Phelps Program Management.

Photo courtesy Polshek Partnership Architects.

JUROR COMMENT

"Innovative structural design that blends well with the surroundings."

The William J. Clinton Presidential Center, located in a park along the Arkansas River in Little Rock, AR features innovative connections and exposed structural steel in its Museum Building. Reminiscent of nearby train trestles, the building's five-story steel structure, measuring 420' long by 46' wide, is supported by a pair of 37'-deep trusses. The trusses cantilever 90' at each end of the building and are supported at three locations with a maximum clear span of 150' between supports.

The museum's main floor, which supports both the mezzanine level above and the mechanical level below, frames into the truss bottom chords. These bottom chords are built-up from steel plates to form boxes that measure 26" deep and 16" wide. Similar to the bottom chords, the truss top chords receive the roof framing, which in turn supports a private retreat for the Clinton Foundation located at the top of the building. Like the bottom chords, the top chords are built-up steel boxes, measuring 30" deep and 16" wide. The architecturally exposed box-shaped built-up diagonals of the building are kept at an outside dimension of 16" x 16" throughout. The decision to make the chords and the diagonals the same width was driven by architectural concerns and also allowed for relatively simple connection details that facilitated fast-paced construction.

At the north end of the building, the trusses are supported on a Vierendeel frame-type steel pier structure made up of box-shaped built-up members, forming a moment frame. The pier is capped by a 95-ton transfer girder that measures 12' deep, 3' wide, and 48' long. This transfer girder cantilevers in both directions to support the trusses. A special pin-support detail was developed atop the transfer girder to allow for rotation of the primary trusses without inducing secondary stresses into the pier.

To accommodate architectural and mechanical considerations, the pier structure is located off center with respect

Structural Engineer
Leslie E. Robertson Associates (LERA), RLLP, New York

Engineering Software
ETABS
RISA-3D

Owner
Clinton Presidential Foundation, Little Rock, AR

Architect
Polshek Partnership LLP, New York

Fabricator and Detailer
AFCO Steel, Inc., Little Rock, AR, AISC member, NISD member

Detailing Software
AutoCAD

Erector
Derr Steel Erection Co., Euless, TX, AISC member

General Contractor
CDI Contractors, LLC, Little Rock, AR

Photo courtesy Phelps Program Management.

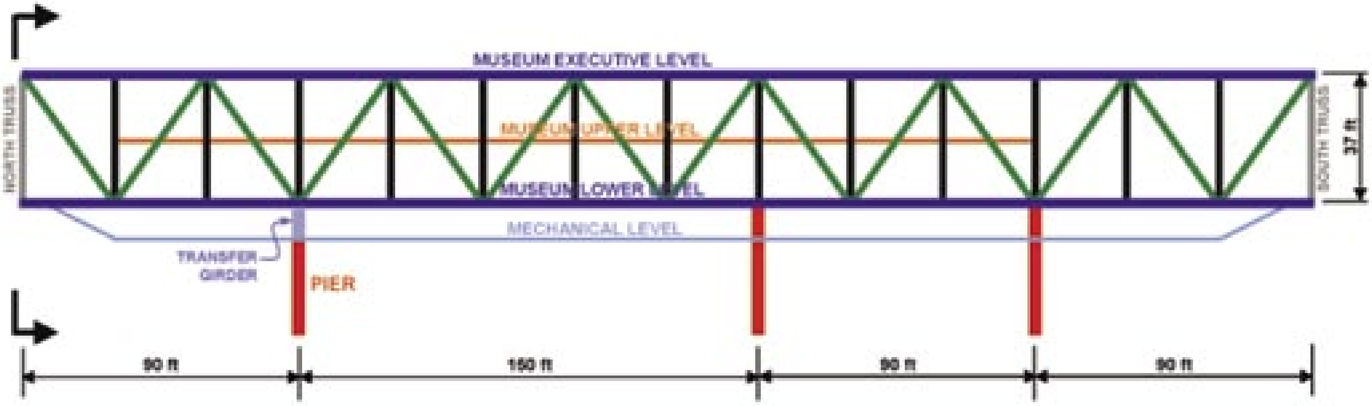
to the building's center of gravity. The resulting twisting forces are delivered to the building's shear walls by horizontal trusses located in the floor diaphragms at both the top and bottom chord levels. The horizontal trusses in the floor framing at the top and bottom chord levels act as collector and drag members that deliver lateral wind and seismic forces to the building's shear walls. They also act to provide stability during construction prior to the casting of the composite concrete floor diaphragms.

Vertical built-up box mullions, hung from the built-up box-shaped cantilever beams, carry both the balconies and the curtain wall. The lower level balcony is supported by beams cantilevering from the bottom chord of the truss. These beams provide lateral support at the bottom of the curtain wall mullions while allowing for vertical sliding, thereby allowing the balcony to move independently of the curtain wall.

For the western façade, double wall construction was used with the outer curtain wall cantilevering from the western face of the building. The resulting separation forms a space containing exterior balconies and museum areas that are shaded from the sun.

The goal for the entrance canopy was to provide a minimum structure where each part of the canopy is called upon to do work. Here, glass is configured to cantilever out from steel bars that pivot from a round bar. The columns supporting this bar are simple plate structures that cantilever up from foundations cast below the plaza paving. The result is a lightweight and transparent canopy.

Steel structure made possible this open and accessible building that reflects President Clinton's aspiration to "put things in the light." ★



TRUSS ELEVATION

Graphic courtesy Leslie E. Robertson Associates.

$25M OR GREATER, BUT LESS THAN $100M

MERIT AWARD

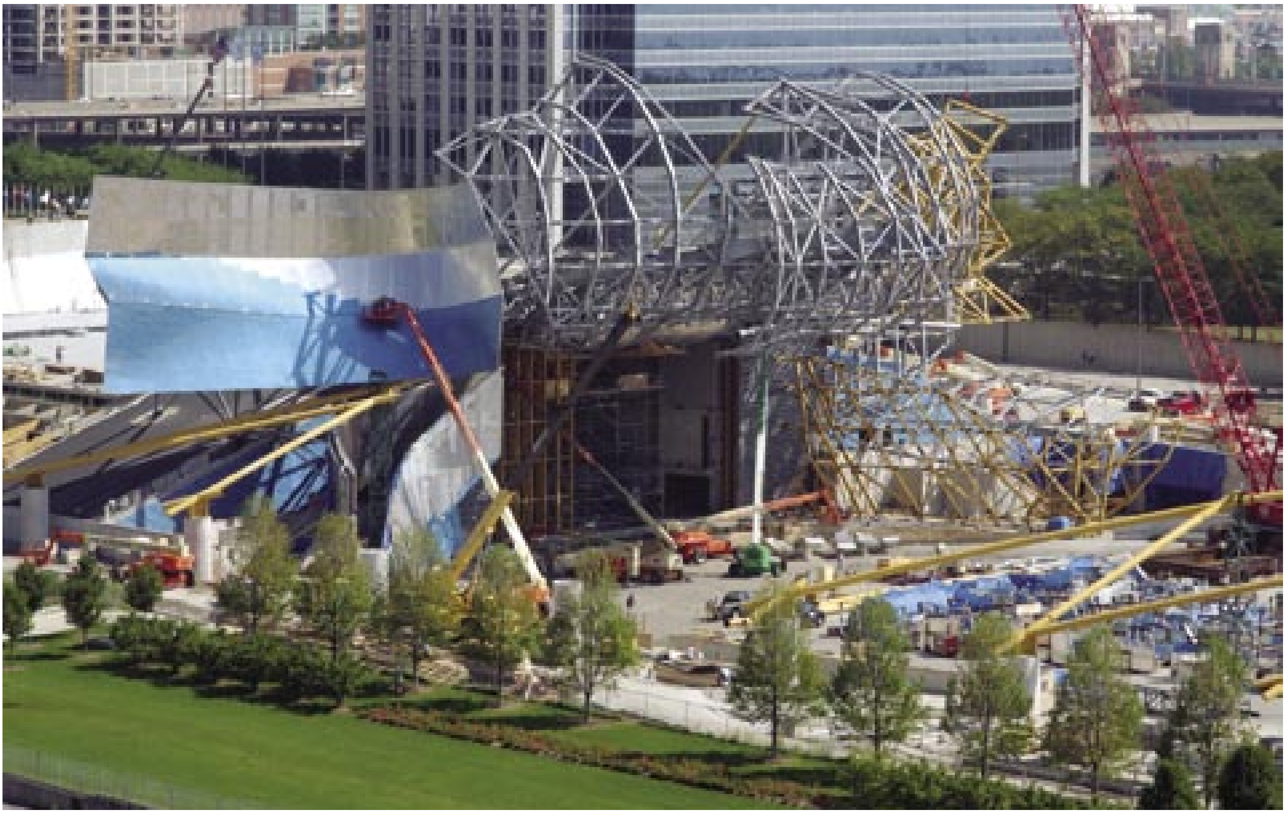


Photo by Peter Barreras.

Jay Pritzker Pavilion

Chicago

The Jay Pritzker Pavilion in Chicago's Millennium Park houses an orchestral stage area framed by enormous metallic forms designed and placed to improve the outdoor venue's acoustic characteristics.

The pavilion is composed of a south-facing bandshell housing the stage and related support facilities, which in turn support the metallic forms. The central portion of the bandshell roof cantilevers up to 100' beyond the proscenium door. There are a total of twelve individual metal-clad assemblies arranged around and above the central stage, forming an overall composition some 300' wide by up to 120' tall. Behind the upper metal surfaces, a system of inclined steel pipe struts connected to the bandshell structure stabilizes the metal elements.

A steel grid/ribbed frame concept was developed for the support of the metal elements, which proved to respond well to the diverse structural system requirements of the project. The structure was configured to closely follow the curvature of the shapes to take advantage of the inherent geometric stiffness of each form.

The basic structural system concept was developed and refined using computer-based surface modeling. First, a structural working surface was generated 2' behind the clad surface. Vertical slicing planes at 9'-8" centers and horizontal planes at 10' centers were electronically passed through the structural working surface. The intersections created the structural work points. Straight line segments connecting the work points formed an electronic wireframe representing the centerlines of the structural grid/frame members.

For this type of structure, with relatively few (450) steel tons, considerations other than least weight were far more important in terms of overall economy. To promote repetition and control of steel connection detailing and fabrication, as well as coordination with cladding systems and attachments, member sizes were standardized throughout the metal elements. Independent, parallel structural analysis

Structural Engineer
Skidmore, Owings & Merrill LLP,
Chicago

Engineering Software
SOM AES software
S-FRAME
SAP2000

Architect
Gehry Partners LLP, Los Angeles

Detailers
Dowco Consultants, Ltd.,
Burnaby, British Columbia, Canada,
AISC member, NISD member

Industrial Detailing, Inc. (trellis),
St. Louis, AISC member

Detailing Software
Tekla Structures
SDS/2 (trellis)

Fabricators
Lejeune Steel Company,
Minneapolis, AISC member

ACME Structural, Inc. (trellis),
Springfield, MO, AISC member

Erector
Danny's Construction Company,
Shakopee, MN, AISC member

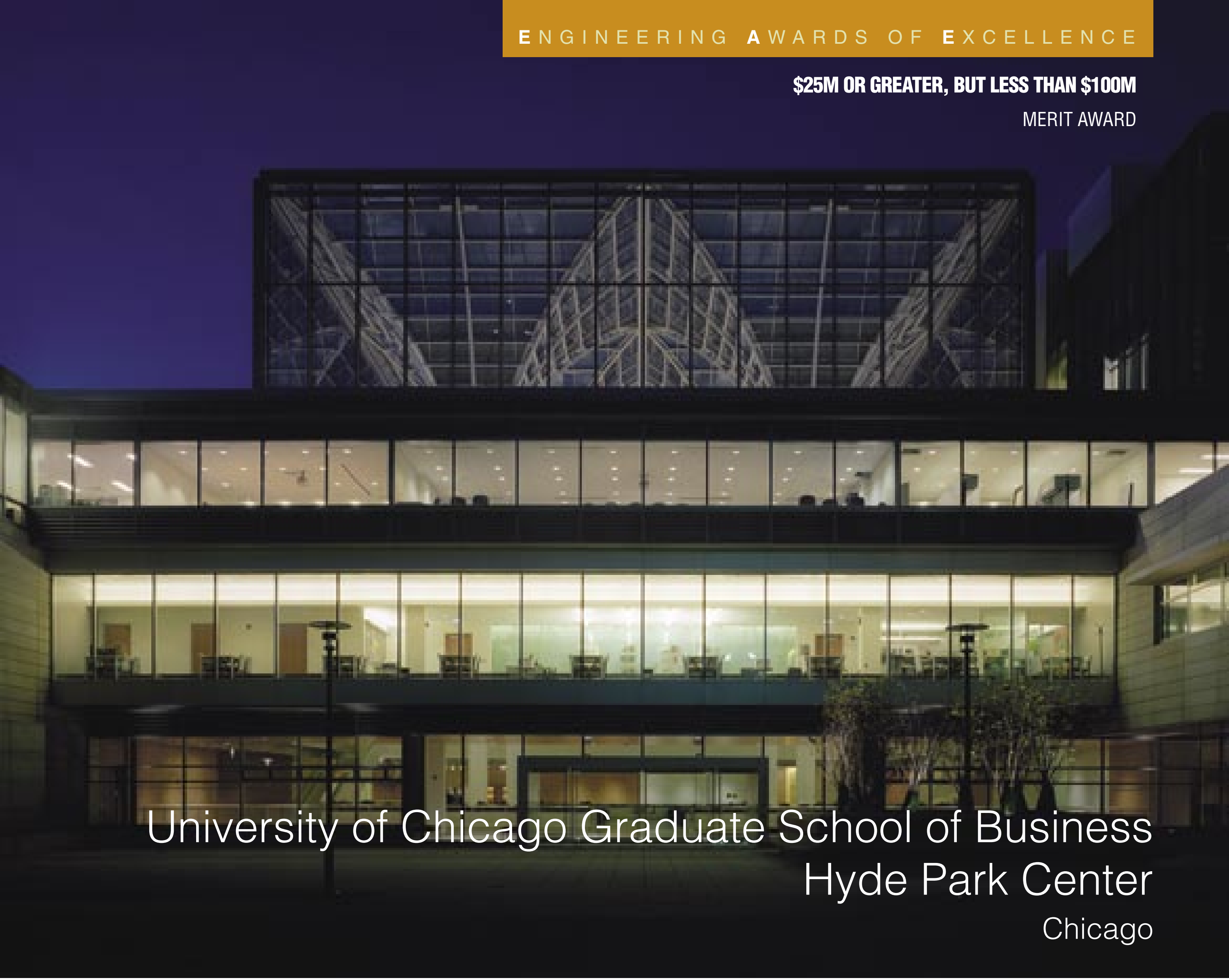
Photo by Peter Barreras.

and design checks were done using two commercially available software programs, S-FRAME and SAP2000, for a complete loading regime including wind, temperature, snow, ice, and live load.

The drawings, together with the computer wireframe, were issued to the contractor as part of the project documentation. The steel detailers converted the wireframe electronic data into Xsteel for use in the preparation of shop drawings for the structural steel. The fabrication/erection concept was to prefabricate vertical sections of each metal element in the shop, trial fit and pre-assemble each section to neighboring sections in the shop, prepare the members for shop painting, and ship them to the site.

A 625' by 325' shell-shaped trellis structure, formed by arched steel pipes, defines the audience space and connects the stage to the great lawn. The trellis structure supports a system of speakers, eliminating the need for speaker towers.

Read more about Jay Pritzker Pavilion in “Music in the Park” in the August 2004 issue of *Modern Steel Construction*, available online at www.modernsteel.com. ★



$25M OR GREATER, BUT LESS THAN $100M

MERIT AWARD

University of Chicago Graduate School of Business Hyde Park Center

Chicago

Photo courtesy Feinkopf Photography.

Structural Engineer
Thornton-Tomasetti Group, Chicago

Structural Engineer Sub-Consultant
Dewhurst MacFarlane and Partners, New York

Engineering Software
RAM Structural System
SAFE
FloorVib 2
SAP2000

Owner
University of Chicago Graduate School of Business, Chicago

Architect
Rafael Viñoly Architects, PC, New York

Detailer
LTC, Inc., La Crosse, WI, AISC member

Detailing Software
DetailCAD
AutoCAD

Fabricator and Detailer
Zalk Josephs Fabricators LLC, Stoughton, WI, AISC member

Erector
AREA Erectors, Inc., Wheeling, IL, NEA member

General Contractor
Turner Construction Co., Chicago

The University of Chicago Graduate School of Business opened its new Hyde Park Center in September 2004. The 415,000 sq. ft academic facility is comprised of a base building with five above-grade levels and two below-grade levels, and a glass-enclosed Winter Garden. The complex features 12 classrooms, 31 group-study rooms, faculty offices, computer labs, multipurpose rooms and an underground parking garage for 170 cars.

In total, the base building used approximately 3,000 tons of structural steel, of which 500 tons were plate girders. The lateral system consists of braced framing located around the cores within the base building "square," as well as one braced frame in the southeast wing. The base building's lateral system is independent from that of the Winter Garden at the ground floor.

Photo courtesy Feinkopf Photography.

To isolate the systems, ground-level bridges that link the base building to the Winter Garden are on slide bearing connections.

The design called for massings to project over the building entrances below. The resulting cantilevers ranged from 3' to 42' and required over 600 moment connections. The cantilevers were often supported by transfer columns, while non-typical deflections were accommodated into the design and installation of the cladding. Spacer posts were used at the perimeter of projecting massings to limit differential deflections between floors.

More than 100 column transfers were required to achieve the column-free spaces in the center's multi-function room and the lower-level classrooms and parking levels. Plate girders varied in depth from 30" to 73", depending on architectural requirements, and weighed from 283 to 1,528 lb per linear foot. When service reaction loads for plate girders exceeded reasonable design limits for shear connections, a bearing connection was used to eliminate the effects of the eccentricity on the support column.

The Winter Garden is framed with structural steel and clad entirely with glass, soaring 83' at its apex. The garden's roof is supported by four main columns. Each column comprises eight 9"-diameter steel pipes with 1-5/8" walls clustered together to create a single column with an overall outside diameter of 33". The column bases are located at Lower Level 1, and diagonal bracing hidden in a demising wall of this level braces the columns at the ground floor. The columns rise nearly 43' above the ground floor as a vertical cantilever. They were fabricated in two sections, with the column splices hidden within the ground floor slab.

The eight pipes of each main column branch out to become roof rafters. The rafters curve to form intersecting Gothic arches, which create roof "funnels." As they rise nearly 40' above the tops of the columns, the rafters taper from an outside diameter of 9" to just 6". They support continuous purlins spaced approximately 6' on center. The purlins, rectangular tubes with outside dimensions of 6" by 3", support the roof glazing and provide bracing for the slender rafters. The four roof funnels, one centered on each of the four main columns, are interconnected to form the 96' by 96' roof.

The third floor of the base building cantilevers out 12' to support the glass walls that enclose the Winter Garden. Wall framing consists of 14" by 3" hollow mullions fabricated from 3/4" steel plate and 4.5" by 1" steel bar transoms. Mullions are spaced at 6' on center, while the transoms are aligned with the fourth, fifth, and sixth levels of the base building. The wall framing was fabricated as a series of "ladders," with two adjacent mullions and the transoms between them shop welded into a single assembly. As each "ladder" was erected in the field, the transoms between each assembly were installed using countersunk high-strength screws tapped directly into the mullions. At the fourth floor, sloping beams support a glass skylight and brace the Winter Garden wall back to the floor diaphragm of the base building.

Resistance to lateral loads is provided by three systems: the cantilevered main columns, out-of-plane bending of the perimeter wall mullions, and the in-plane rigid tube frame (mullions and transoms) of the perimeter walls.

Read more about the Hyde Park Center and Winter Garden in "Class Act" in the November 2004 issue of *Modern Steel Construction*, available online at www.modernsteel.com. ★

Photo courtesy Feinkopf Photography.

$10M OR GREATER, BUT LESS THAN $25M

NATIONAL WINNER

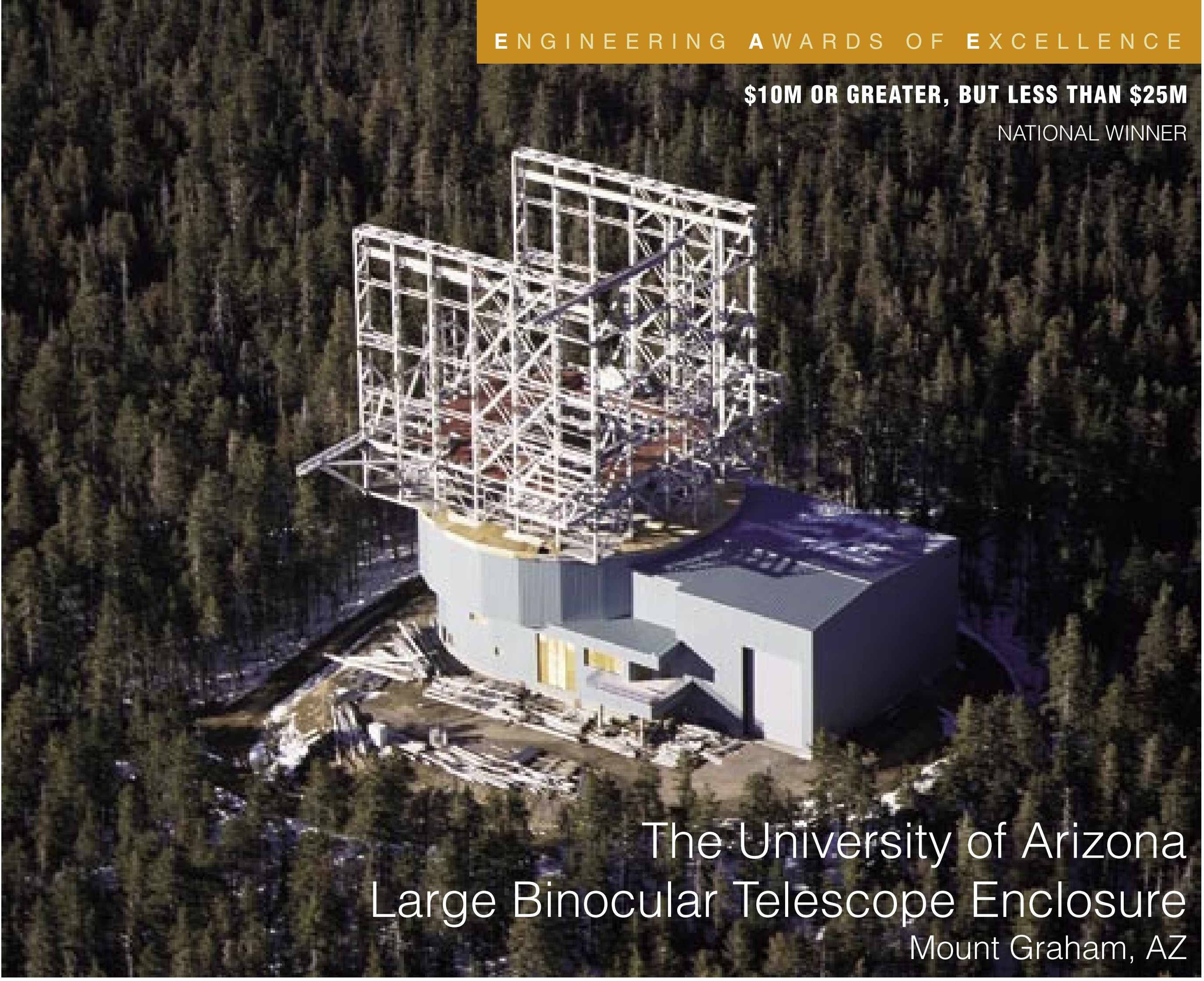


Photo by Stephen Criswell.

The University of Arizona Large Binocular Telescope Enclosure

Mount Graham, AZ

JUROR COMMENT

"A precision structure, with very tight tolerances, designed for unusual loads—movement of the structure due to environmental loads, rotation of the telescope, and thermal loads—not usually significant for structural designs."

The University of Arizona's Large Binocular Telescope (LBT), located on Mount Graham in southeastern Arizona, houses an optical telescope in the equivalent of a 12-story building that rotates on a 38'-high circular concrete wall foundation. Tolerances for design and construction varied from as coarse as 1/16" to as fine as nanometers for the optics.

In addition to the basic loading criteria, several operational elements were incorporated into the design of the rotating enclosure including: bi-parting building walls and roof to allow observation, a 55-ton overhead bridge crane, side and rear ventilation doors, a roof snow-melting system, a service elevator, and access platforms for shutters, the elevator, and a weather station.

The enclosure structure is co-rotating—it rotates with the telescope, although by separate drives. To maintain accuracy of observation, the telescope structure must be independent from the building structure. The main rotating structure is a rectangular prism, 105' by 95' by 115' high. The available site, cleared within Coronado National Forest, was limited by permit. The building footprint needed to be minimized, resulting in urban-type construction.

With an overall building height of 168' above grade, the rectangular prism structure has a system of steel beams and columns with braced frames to carry loads down to a three-dimensional steel truss system supported by four bogie drive assemblies. Some fabrication weighed as much as eight tons, while the load transmitted to the support bogies was

Structural Engineer and Architect
M3 Engineering & Technology Corporation, Tucson, AZ

Engineering Software
COSMOS/M

Owner
LBT Corporation, Tucson, AZ

Detailer, Fabricator, and Erector
Schuff Steel Company, Phoenix, AZ, AISC member

Detailing Software
AutoCAD

General Contractor
Hart Construction Management Services (HCMS), Safford, AZ

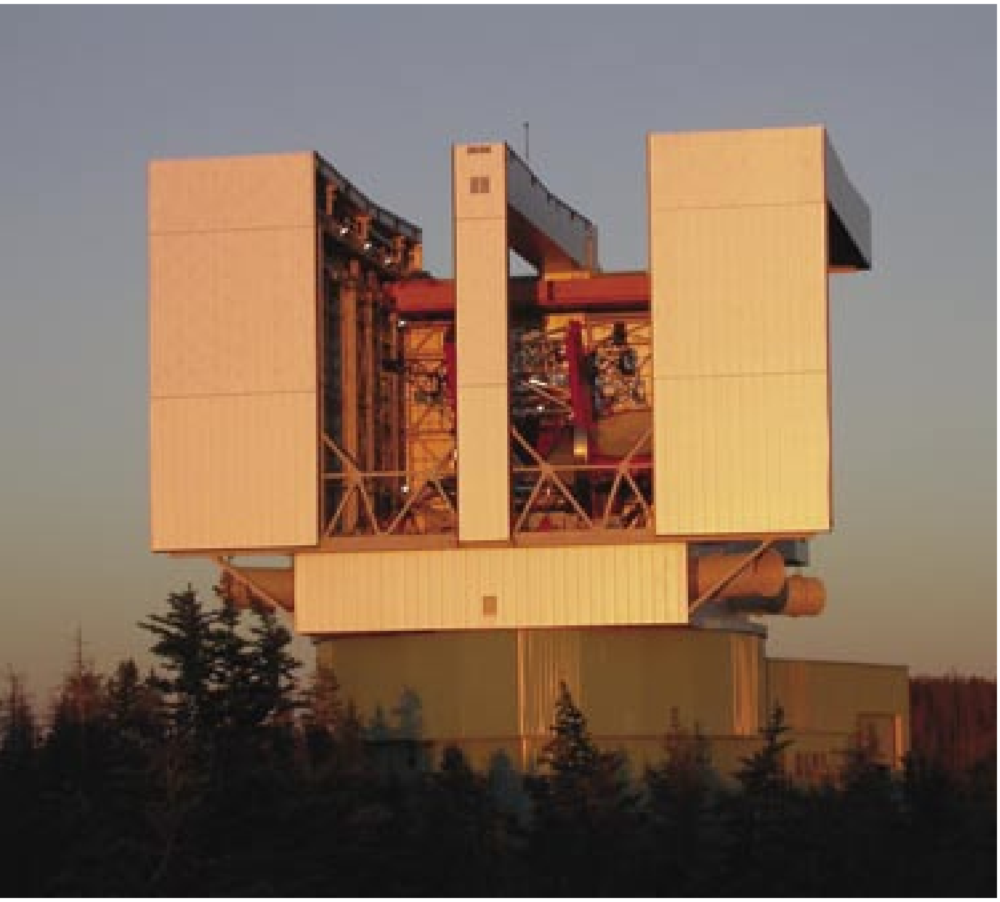


Photo by John Hill.

approximately 2,000 tons. The bogies rotate this mass at up to 2° per second to maintain alignment with the telescope. Bogie assemblies are mounted on a circular steel track 38' above grade.

Displacement control of the structure for operating wind load cases was accomplished by optimal use of diagonal stiffening of the structure. Survival wind load displacements are controlled by latch mechanisms designed to tie the moving parts of the structure together to accomplish lateral stiffening and reduce displacements to acceptable levels.

The rotating enclosure structure consists of eight levels, including a bogie level, a mechanical equipment room, an observation level, a visitors' gallery level, an elevator equipment room, a crane access level, a meteorological level, and a snow-melting roof. The design criteria were as follows:

- Wind speed with telescope operational: 45 mph (shutters open)
- Wind speed with shutters open: 90 mph (telescope not in operation)
- Wind speed survival: 125 mph (shutters closed)
- Base elevation: 10,720' above sea level
- Snow load: 90 psf
- Ice load: 60 psf
- Overhead crane: 55-ton capacity
- Seismic: UBC Zone 2B

Steel framing forms a box with the observing level at the bottom, two fixed walls on the sides that carry the overhead crane runway, and a fixed wall behind the telescope that houses the elevator. The two sidewalls and a back wall incorporate horizontal rolling ventilation doors. Two 33'-wide moveable shutters, one for each of the telescope's 8.4 m primary mirrors, are "L" shaped. The vertical 93'-high leg of each shutter forms the wall in front of the telescope and the 100'-long horizontal leg forms the roof of the box.

Open configuration lattice columns and bracing with thicknesses less than 3/4" were used to minimize the thermal mass of the structure and to increase thermal response to air temperature changes.

The fourth level mechanical room is an interstitial space of the 16'-deep two-way trusses consisting of steel wide-flange chords diagonals and verticals. The interstitial space houses the mechanical and electrical support systems for the telescope.

The LBT enclosure structural design incorporated details to facilitate erection on Mount Graham at 10,720' elevation. The access road up to Mount Graham has several tight curves, limiting the maximum length of a piece to 40'.

All bolted connections were specified as slip critical due to the dynamic nature of loads on the structure. Stress reversals are common during operations. Due to the geometry of the structure, the sidewalls that support the crane rails will move laterally when the shutters are opened and closed. Also, lateral deflections due to wind will affect the operation of the crane as the crane rail supports move in and out.

In order to control the deflections within operational limits for door seals and crane operation, an exterior structural skeleton was provided to both reduce the deflections due to shutter movement and wind loads. The unique configuration of the LBT enclosure combined with the environmentally decreed tight site provided interesting challenges to the structural steel design and erection. Steel provided the flexibility and light weight required for the unique functions of the structure. ★

$10M OR GREATER, BUT LESS THAN $25M

MERIT AWARD

St. Martin's Episcopal Church

Houston

Photo by Christof Spieler.

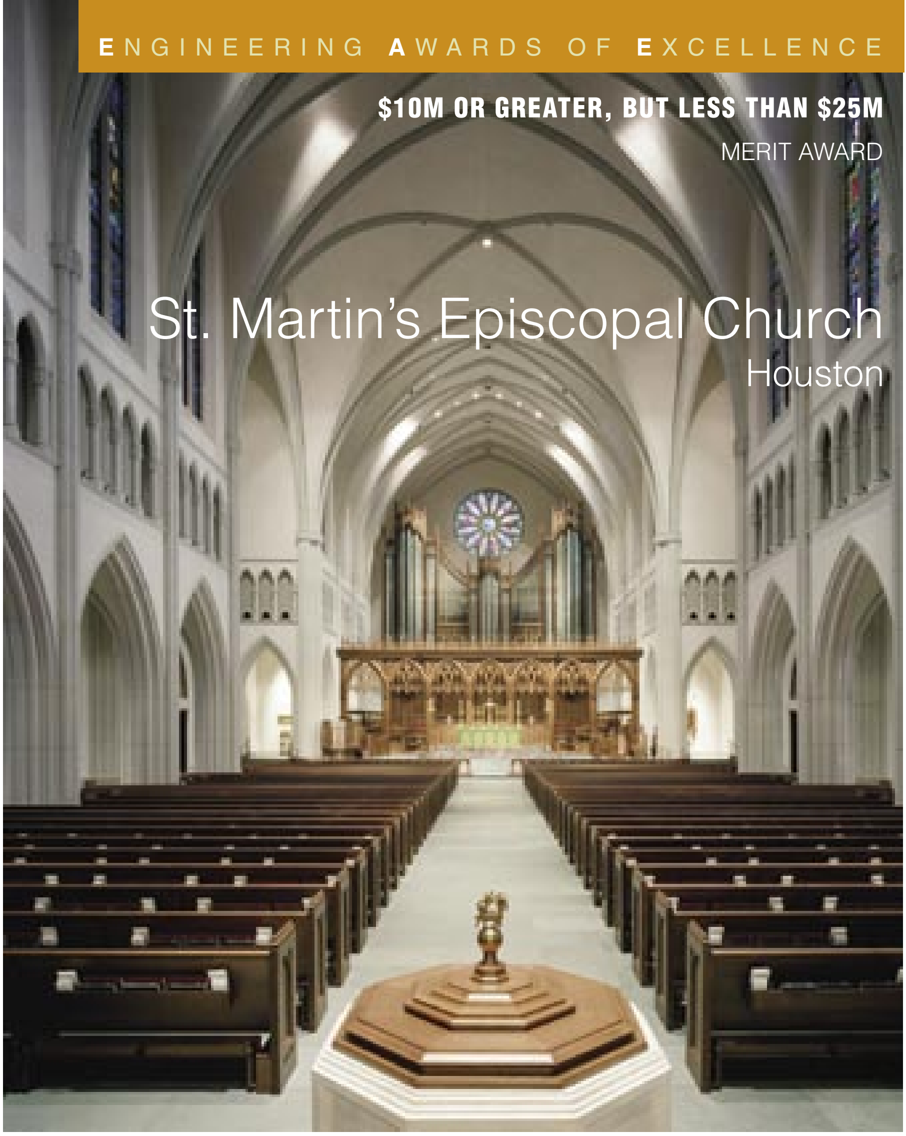


Photo by Mark Scheyer.

Structural Engineer
Matrix Structural Engineers, Houston

Engineering Software
RISA-3D
RAM Steel

Owner
St. Martin's Episcopal Church, Houston

Architect
Jackson & Ryan Architects, Houston

Erector
Steel Masters, Inc., Houston, SEAA member

General Contractor
Tellepsen Corporation, Houston

For the new sanctuary of St. Martin's Episcopal Church, the design team worked hard to capture the form and details of a Gothic cathedral. Beneath the structure, however, the buttresses and pointed arches are anything but traditional.

Gothic architecture was the owners' request. The design team's job was to make it work with a $20 million budget and a tight schedule. Work on design development started in December 2000 and the building had to be completed exactly four years later. The challenge was to replicate, in modern materials, the forms of an architecture based on load-bearing masonry.

Several structural systems were considered for this unconventional building. A hybrid system of steel and concrete was considered. But the final choice was what had been sketched in the first design team meeting: a series of steel frames forming the nave, spaced at 16' on center to match the architectural module, and two X-braced steel structures forming the towers.

Each steel frame, 80' wide at the base and 87' tall at the peak, carries the wind loads for a 16' strip of the façade. The main columns are W27×146. Below 32', the main columns are connected with moment connections and angle braces to the beams and columns of the aisle. Above 47', the columns are joined to the gabled roof truss, which is made up of a wide-flange top chord and double angle diagonals. Under wind loads, the main columns bend in an "S" shape due to the fixity from the aisle frames and the roof truss. No column base fixity was counted on for strength calculations. With allowance made for some fixity, lateral deflection under 110 mph winds is less than 1/300th of the height.

As soon as the steel frames were erected, it was obvious that these were the "bones" of a Gothic church. The diagonal braces of the aisle frames form the arches of the aisle ceiling, and the beams above form a classic triforium, used here for air conditioning ducts. The underside of the roof truss forms the shape of the vaulted ceiling.

Between the frames are tall stained glass windows. To meet deflection requirements, these had to be braced to the W27 columns. A steel frame around the window—fabricated to exact dimensions so the windows would fit in without blocking—is attached to steel tubes welded to the sides of the columns. Several different distributions of wind were evaluated to make sure the columns would not twist excessively under this load.

The towers posed their own problems. The steel structure extends to 108', and above this are 80'-tall pre-engineered steeples. Four W14×176 columns form the corners of the tower. Above 47', the columns are connected with double angle X-braces and ring beams. Below that, the opening for the balcony stairs and a large stained glass window eliminate both east-west X-braces in the tower. A series of girts, sloping beams, and diagonal braces concealed in the tower buttresses transfer the wind loads sideways and down to the ground.

Because the tower brick extends 128'

up and steps back often, shelf angles spaced 8’ to 15’ vertically provide for brick support. A system of tubes wraps around the towers at every shelf angle, following the shape of every buttress, pier, and wall. These are supported on outriggers off the main tower columns or on buttress beams, and are designed to take both the vertical brick load and the horizontal wind loads.

The remainder of the structural system is fairly conventional; roofs are metal deck on steel joists and floors are concrete slab on metal deck on wide-flange beams. The roofs of the aisle and nave are framed with sloping steel bar joists spaced 5’-4” on center. Deep, long-span metal deck was considered early on to eliminate the bar joists, but discussions with the construction team revealed that joists would be useful for supporting the plaster ceiling, lights, and maintenance catwalks. Point loads were specified on the construction documents and the joists were designed to allow these loads to be placed at any point along the joist.

The general contractor and key subcontractors, including the steel fabricator and erector, were brought in early in the design process. Matrix structural engineers worked directly with the steel detailer to answer questions rather than go through a formal RFI process, and shop drawings were submitted in multiple packages to allow fabrication to begin as detailing continued. The result: The building was completed on schedule and in time to install the pipe organ before the first service, Easter 2004. ★

Photo by Christof Spieler.

$10M OR GREATER, BUT LESS THAN $25M

MERIT AWARD

Photo courtesy KL&A, Inc.

Robert Hoag Rawlings Public Library

Pueblo, CO

Graphic courtesy Antoine Predock Architect.

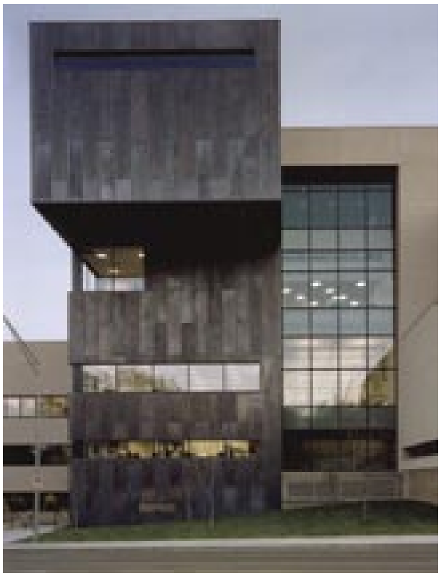


Photo by Timothy Hursley.

Pueblo's new Robert Hoag Rawlings Public Library serves as a meeting place, a gallery for art and permanent displays, and a location for special events. The 109,000 sq. ft structure uses bold architectural forms and the juxtaposition of architectural finishes—with conventional composite steel framing in most areas—to create interest and drama on a budget.

The first structural challenge was an overhead structure spanning approximately 98' and connecting two sides of the library on opposite sides of a street. This "skyway" included two levels of library stacks and administration spaces, as well as mechanical equipment behind tall, sloping parapets on the roof. The plan geometry of the skyway was trapezoidal in shape, with a glass-clad triangular hole through the middle, allowing light in and a view of traffic passing below. Four one-story tall trusses are located at the third floor level, with the second floor level suspended below. Directed spherical bearings were used to allow free movement due to rotations at the ends of the trusses and thermal movement.

The library's most prominent structural steel feature is a wedge-shaped trellis. It forms a point starting at the north side of the building that descends at 4° for 368', ending in a 45'-long cantilever that is only 2'-9" deep at its spring point. The trellis is made of built-up, wedge-shaped tube sections connected by channel sections and diagonal flat plate braces. At the north side of the building, the deep end of the wedge contains a gallery that cantilevers 16' beyond the face of the building. This was accomplished with a steel moment frame that allowed side windows in the gallery.

The main stair in the atrium lobby cantilevers 20' from the slab edge support. However, the landing at the end of the cantilever—typically a stiff element that resolves the forces between the structural stair runs—is 22' long. An HSS 16×16 member was used to connect the stair runs. A splice was required in this HSS member to make the stair compo-

Structural Engineer and Detailer
KL&A, Inc., Golden, CO,
NISD member

Engineering Software
AutoCAD
RISA-3D
RAM Structural System

Detailing Software
SDS/2

Owner
Pueblo City-County Library District,
Pueblo, CO

Architects
Antoine Predock Architect PC,
Albuquerque, NM (design)
Anderson Mason Dale Architects,
Denver, CO (executive)

Fabricator
Zimkor LLC, Littleton, CO,
AISC member

General Contractor
H.W. Houston Construction Co.,
Pueblo, CO

nents portable and constructible, but the architectural finishes did not allow for any plates or other protruding elements. A completely field bolted splice was devised that fit entirely within the shape of the HSS to meet these challenges.

The 54'-tall atrium glass wall was achieved with minimal structural support by providing horizontal tube-steel girts at the floor levels, with slender sag rods supporting the girts from above.

Perhaps as important as the building's structural elements was the project delivery approach, driven by the needs of the owner and contractor to meet a tight schedule. Structural engineering firm KL&A employed its own in-house steel detailing staff, using the 3D steel-detailing/modeling package SDS/2. Detailers were able to start work on the 3D model during the construction documents phase, which in turn resulted in the issue of complete shop drawings shortly after the final issue of structural construction documents, and before the final architectural package was released. ★

LESS THAN $10M

NATIONAL WINNER

Photo by Paul Turang Photography.

Desert Bloom Porte Cochere

Cabazon, CA

With large "petals" stretching into the desert sky, the Desert Bloom Porte Cochere of the Morongo Casino Resort and Spa has become a recognizable landmark for the Cabazon, CA getaway.

The initial concept and geometry of the Desert Bloom structure was developed by The Jerde Partnership as a series of overlapping, truncated double-curved surfaces, or petals, that originate from a central node and spiral outward.

The use of computer modeling and analysis between the architects and structural engineers was integral to the successful completion of the project. The architects' original AutoCAD 3-D structural model was used as a basis for structural design and detailing. Under a design/build contract, structural engineers ASI Advanced Structures developed and presented an innovative structural scheme comprised of four separate petals and a central light tower. Each petal rises 40' and spans 120' on average. The surface area of the entire structure covers approximately 27,000 sq. ft.

The structure had to be as thin, efficient, and light as possible, prompting a single layer steel grid shell frame with a typical structural member depth of 10". The typical shell structure requires a single or double curved surface geometry with rigid boundary restraints to resist in-plane or out-plane loads. All out-of-plane service loads are transformed into in-plane forces within the shell structure with some flexural forces in the ribs. These forces are collected in the 18" nominal diameter pipe edge member, which are eventually resisted by the boundary foundation and building column support structure.

In order to facilitate fabrication and erection, each of the four petals was divided into a series of individual curved wedge shape segments ("ladder" frames). The dimensional division of the petal was limited by the fabrication facilities and transportation logistics of each ladder. The ladders were fabricated using two rolled edge (MC10×8.4) channels forming the main radial ribs of the petal. HSS 4×4 struts laced the ribs together. The complexity of the geometry

JUROR COMMENT

"Excellent execution through collaboration in a design/build process."

Structural Engineer
ASI Advanced Structures Inc.,
Marina del Ray, CA

Engineering Software
SPACEGASS

Detailing Software
AutoCAD
Mechanical Desktop

Owner
Morongo Band of Mission Indians,
Banning, CA

Architects
The Jerde Partnership, Venice, CA
(design)
Thalden-Boyd Architects, Tulsa, OK
(executive)

General Contractor
Perini Building Company, Inc., Phoenix

Photo by Paul Turang Photography.

meant that all of the HSS struts had to be mitered at different angles, and in some cases with a double-mitered cut.

The division of each of the petals into lightweight ladders made the process of fabrication, shipping, and installation relatively simple and straightforward. The ladders were bolted together in the field with galvanized steel bolts. The 40' sections of rolled, curved pipe were spliced together in the field. The double curvature was achieved by twisting each successive piece of a single rolled section.

A key factor in the erection strategy involved setting up a detailed shoring plan for each of the four petals in the structure. This was required to stabilize the shell until the structure was tied together through the bolted connections and to support the construction loads generated by the complex geometrical shapes. The shoring remained in place until all of the petals were fully assembled, and the combined frames of all four petals were tied together.

The central light tower stands 60' tall. It was fabricated in two sections that were bolted together in the field. Approximately 350,000 lb of custom-fabricated steel, and more than 5,000 bolts, were used for the $2.8 million project. ★

LESS THAN $10M

MERIT AWARD

Davis Conference Center

Layton, UT

Photo by Jacom Stephens.

The Davis Conference Center was designed to provide state-of-the-art convention and reception spaces to the communities of northern Utah. The 42,420 sq. ft conference center, built adjacent to an existing hotel, houses a grand ballroom with movable partitions that can be used to divide the space into eight smaller areas. The facility also includes smaller meeting rooms and reception areas connected by a concourse that runs the length of the facility, terminating at a steel and glass turret.

The ballroom and meeting rooms on either side of the concourse feature conventional steel framing and chevron braces. The concourse was framed separately with 8” square tube columns supporting a barrel-vaulted roof constructed of rolled tubes.

A large component of the vision for the project was to provide open clerestory windows within the concourse that would be unobstructed by the presence of bracing. The main concourse roof diaphragm is significantly higher than the rest of the building. To provide lateral stability without using bracing or moment frames in the concourse, steel slip collar connections were added to each concourse column at the level of the adjacent braced roof diaphragm. The slip collars were designed to transfer lateral shear forces directly from the concourse columns to the braced portions of the building on either side. They were also designed to slip to accommodate anticipated deflections in the adjacent roof structure from snow or live loads.

To prevent undesirable sound transfer through the slip collars, each column was wrapped with an adhesive-backed elastomeric material at the connection to

Structural Engineer
ARW Engineers, Ogden, UT

Engineering Software
RAM Steel
RISA-3D

Owner
Davis County Gov. Dept. of Economic Development, Farmington, UT

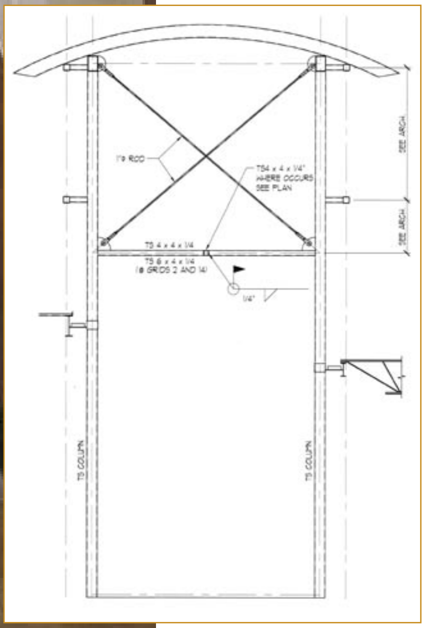
Architect
Gillies Stransky Brems Smith, Salt Lake City

General Contractor
Sahara, Inc., West Bountiful, UT

deaden sound transmission. This method of lateral support eliminated the need for any transverse bracing along the length of the concourse. Only minimal bracing was required in the longitudinal direction at the ends of the concourse where the elevation difference between concourse and the adjacent roofs was the greatest.

The architectural design called for two 70'-tall freestanding towers to be constructed at the main entry. The towers were clad in sandstone veneer and support 15'-tall exposed aluminum frames. This presented an engineering challenge due to high seismic forces generated by the weight of the sandstone veneer and the high design wind loads required by city ordinance. To design a stable framing system for the towers, three dimensional computer models were developed and subjected to the design earthquake and wind forces. The results indicated that the towers could be efficiently constructed using 5" square steel tube segments with fillet-welded connections. Metal stud infill framing and plywood sheathing provided the backup to anchor the sandstone veneer. ★

Photo by Jacom Stephens.



Graphic courtesy ARW Engineers.