2003

EAE

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 will be considered as 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, 1999 and December 31, 2002.
- Projects must be located in the U.S., Canada or Mexico.

Judging Criteria

- Creativity in response to the owner's and architect's program.
- Application of new or innovative technology in areas such as connections, gravity systems, lateral load resisting systems and fire protection.
- Structural efficiency.
- Significance of engineering achievement.

2004 Jury

- Lawrence A. Fuess, P.E.
  Principal
  L.A. Fuess Partners, Inc.
  Dallas
- Kenneth Gibble, P.E.
  Principal
  Gibble Norden Champion Brown, Inc.
  Old Saybrook, CT
- James O'Callaghan
  Engineering Director
  Dewhurst Macfarlane and Partners
  New York

AWARD WINNERS

$100M or greater

NATIONAL WINNER
Reliant Stadium—Houston
Walter P. Moore and Associates, Inc.

MERIT AWARD
Seahawks Stadium—Seattle
Magnusson Klemencic Associates

MERIT AWARD
The James H. Clark Center—Stanford, CA
Middlebrook + Louie Structural Engineers

$25M or greater, but less than $100M

NATIONAL WINNER
Gerald Ratner Athletics Center—Chicago
OWP/P Structures

MERIT AWARD
Richard B. Fisher Center for Performing Arts—Annandale-on-Hudson, NY
DeSimone Consulting Engineers, PLLC

MERIT AWARD
Hobby Center for the Performing Arts—Houston
Haynes Whaley Associates, Inc.

$10M or greater, but less than $25M

MERIT AWARD
Swonder Ice Arena —Evansville, IN
Jacobs Facilities, Inc.

MERIT AWARD
S.T. Dana Courtyard Infill—Ann Arbor, MI
Structural Design Incorporated

Less than $10M

NATIONAL WINNER
Schubert Club Band Shell—St. Paul, MN
Skidmore, Owings & Merrill LLP

MERIT AWARD
Reiman Gardens Conservatory Complex—Ames, IA
Charles Saul Engineering

MERIT AWARD
Branford Point Residence—Branford, CT
Robert Silman + Associates

Reliant Stadium

Houston

Photograph courtesy Mark Green.

Juror Comment

"An impressive structure accommodating a myriad of complex requirements. The scale of the opening roof and the supporting supertrusses are recognizable feats of structural design."

Reliant Stadium – home of the Houston Texans and Houston Livestock Show and Rodeo, is the National Football League's largest stadium, covering more than 12 acres and comprising 1.9-million sq. ft. It is also the first NFL stadium with an operable roof, and at 3.75 acres it is the largest such roof in the United States. The translucent fabric roof is an architectural landmark for the City of Houston.

The retractable roof structure solves a challenging tenant program by offering the flexibility to play football games in either an open-air environment or in air-conditioned comfort. For the Houston Livestock Show and Rodeo—a major tenant for two weeks every year in late February—the rodeo and its concert events can be held in a closed-building atmosphere, much like an arena. The roof will support 170,000 lb of rigging load for major concert events, comparable to any modern arena. Despite numerous challenges, the project achieved every goal, and in the end was completed within budget and within a fast-track schedule of 30 months.

The distinctive operable portion of the roof consists of two panels that bi-part at the 50-yard line to park behind the end zones. Each 385′-by 500′ panel is framed with five arched trichord trusses, which are clad with PTFE fabric and tensioned between trusses by a major valley cable to form a distinctive anticlastic roof shape. Electric motors connected to roof carriers housing standard steel wheels drive the operable roof on a single 175-lb crane rail to open and close in as quickly as 10 minutes. Use of only two wheels per carrier ensures a determinate system that avoids unpredictable wheel-load redistribution due to rail deflection.

Several other design and engineering innovations were incorporated, including a 4-bar stress-relief linkage invention that isolates the retractable panels from differential rail lateral movements of up to 21″ and a first-of-its-kind computerized clamping system that keeps the panels from "flying away" during high winds. A detail incorporated into the supertrusses allowed the roof rail to be adjusted after construction to meet the tight mechanization tolerances.

An efficient steel structural system supports the operable roof. Two massive trapezoidal supertrusses clear span 650′ between concrete supercolumns along either field sideline. The bottom chord of each supertruss is arched to accommodate the sightlines of the seating bowl, creating a truss with minimum depth of 50′ at midspan and increasing to 75′ at the supports. Beyond the supercolumns, the supertruss cantilevers 164′ further to support the roof in the open position. The depth of the supertruss also serves as a closure wall for the building through a series of tensioned fabric cones woven through the filigree steelwork.

The supertruss responds to its architecturally dictated form through composite action between steel and concrete. To shift moment from the narrow midspan to the deeper regions over the support, the steel supertruss was made integral with the concrete supercolumn to form an enormous composite portal frame. For further economy, the concrete slab atop the supertrusses—required as a working surface for mechanization access—was made composite with the truss top chord to carry compression. The composite steel/concrete supertruss/supercolumn system is believed to be the largest ever used in a building structure.

There are more than 1.5 total linear miles of primary long-span trusses in the roof. A fixed area of fabric roof above the end zones, similar to the movable tri-chords above, extends the bright expanse of fabric roof to the edge of the stadium. Beyond the fabric roof, two box trusses at each end zone span 366′ to support the NFL's largest scoreboards, as well as a significant portion of the mechanical rooms. A hard roof above the sideline seating areas spanning from the supertrusses to the perimeter bowl columns completes the stadium roof. This joist-metal deck side roof is engaged to brace the exposed wall of the supertrusses laterally back to the seating bowl, reinforcing the concept of a unified, composite structural system.

The extensive engagement of concrete in composite action to augment the primary steel system required that several structural models be prepared to examine the variation in properties that could exist in the concrete elements. Three complete structural models were prepared in SAP2000, and the final steel design represents an envelope of all. In addition, extensive finite-element analysis was conducted on the composite action between the supertruss steel top chords and the slab. Bracing provided by the steel floor beams proved critical to enabling the slab to develop its full capacity without buckling.

Providing the integral moment connection between the supertruss and the supercolumn presented a major challenge due to the limited space. Seventy-eight 2.5″ diameter anchor rods extend 20′ into the top of the supercolumn to transfer the moment, the magnitude of which was best quantified in kip-miles. Walter P. Moore prepared a three-dimensional digital placement diagram of the anchor bolts and the maze of reinforcing bars atop the supercolumn to aid the contractor in placement.

Throughout the roof, ASTM A913 Grade 65 steel was used to reduce tonnage. Steel details were developed in cooperation with AISC-member Hirschfeld Steel to facilitate efficient fabrication. Coordination also occurred with the steel detailer, the steel erector, and the fabric supplier through extensive electronic data interchange of structural models, AutoCAD models, and Xsteel models. For example, structural models were provided to the steel erector for use in the detailed analysis of the erection sequence.

The operable roof of Reliant Stadium is the product of countless hours of exceptional effort by engineers, fabricators, and erectors, cumulatively responding to an architectural vision for the City of Houston that could only be realized in structural steel. ★

Read more about Reliant Stadium in the July 2003 issue of Modern Steel Construction *at www.modernsteel.com.*

Architects
Houston Stadium Consultants (HSC), a joint venture of Hermes Architects, Houston, TX and Lockwood Andrews Newnam, Houston, TX

Stadium Consultant
HOK Sports + Venue+ Event, Kansas City, MO

Structural Engineer
Walter P. Moore and Associates, Inc., Houston, TX

Contractor
Manhattan/Beers, a joint venture

Roof Mechanization Consultant
Uni-Systems, Inc., Minneapolis, MN

Roofing Fabric
Birdair, Amherst, NY

Steel Fabricator
Hirschfeld Steel Co., San Angelo, TX (AISC member)

Steel Erector
Derr Steel Construction Co., Euless, TX (AISC, SEAA member)

Steel Detailer
Dowco Consultants, Toronto, CA (NISD member)

Engineering Software
SAP 2000

Detailing software
Tekla Xsteel

Bending Services
Bendco Inc., Pasadena, TX

Seattle Seahawks Stadium

Seattle

Photo courtesy Timothy Hursley.

Photo courtesy Michael Dickter, Magnusson Klemencic.

Juror Comment

"The idea of isolating the mass of the roof structure to resist lateral transfer loads in seismic events reflects a real sense of ingenuity by the engineering team."

The Seattle Seahawks Stadium and Exhibition Center is a $430-million public-private development project. It incorporates a 67,000-seat football/soccer stadium, a 201,800-sq.-ft exhibition hall, and a parking structure on a small site just south of downtown Seattle

The new stadium is located within the space envelope of the old Kingdome, but offers a new experience for spectators: two signature 720′ tied structural steel arches support the stadium roof, and no columns block views of the field, downtown Seattle, the water, or the mountains.

The project was finished one month ahead of schedule and on budget. Even though the stadium has large roof sections and is located in a high seismic zone on liquifiable soils, it cost 7% less on a per-seat basis than the last 13 NFL stadiums constructed.

Steel Innovations

First-Ever Seismically Isolated Stadium Roof. The stadium sits on liquifiable soils in a high seismic zone. In the event of an earthquake, the site's north end could move a foot to the north while the south end moves a foot to the south, potentially stretching or compressing the roof up to 2′. Expansion/contraction due to temperature could be 8″ in the roof. Special bearings known as "friction pendulum dampers," allow the ground/seating bowl to move independently from the roof during an earthquake, isolating the roof from movement and potential damage. The ends of each 720′ roof arch rest on these dampers, located within the roof support pylons. Each damper supports 3 million lb of vertical load. By decoupling the mass of the roof from the rest of the building, it was possible to reduce the design forces on the pylons and foundations. This also saved more than $3 million in the construction cost.

Special Hinged Columns Take Up the Slack. With the potential for the roof to move up to 2′ atop the dampers in the pylons, "hinged columns" support the roof around the back of the bowl to accommodate this movement.

New "Slipped Nickel" Approach. A "slipped nickel," approach to the roof geometry was developed to simplify the roof framing and connections. A uniformly skewed stack of circular, parallel planes (the nickels) became the template for roof geometry, yielding a condition where all roof beams are parallel and equal length, and the roof deck is flat and parallel. This simplified construction, shortened the schedule, and cut costs.

Advanced Shaping Exercise Optimizes Arch Curvature. A sophisticated

Photo courtesy Michael Dickter, Magnusson Klemencic.

Photo courtesy Corky Trewin, Puget Sound Digital.

shaping exercise helped determine the optimum funicular shape of the roof arch. Funicular—or "rope-like"—refers to the concept that between any two points, a rope suspended will hang in a naturally perfect shape under a given set of loads. This translates into an optimized stadium roof arch representing the most economically efficient shape.

Extensive Integration of Steel Detailing into the Engineering Design Process. The structural steel detailer was incorporated as a part of the design team, which allowed all the structural details to be industrially "tested" (using 3-D CAD tools) and included on the structural drawings. This provided bidders more precise information than would normally be available.

New "Erection Structure as Final Structure" Technique. The dramatic tied-arch roof comprises two separately erected elements that work compositely as one. The lower tri-chord truss was built on the ground in seven pieces and lifted on three erection towers. It was then used as a staging platform for the remainder of the roof erection, eliminating the need for additional erection platforms. Next, the dramatic steel arch was erected with 16 A-frame components.

Precision Post-Tensioning Controls Roof Arch Deflection. Each tri-chord truss is post-tensioned with 4.5 million lb in 130 strands. This post-tensioned approach allowed the arches to lift off the erection towers, and final vertical deflections to be precisely controlled.

Dramatic Seating Cantilever. To bring fans as close as possible to the field, the upper deck was cantilevered over the lower deck seating. This creates the longest interior cantilever seating overlap (56′) and the most intimate sightlines in the NFL.

Advanced Vibration Analysis. Specialized wind and vibration analyses were performed on specific elements of the stadium to meet performance objectives. The structural steel tower for the scoreboard—the first portrait-oriented board in an NFL stadium—was subjected to a special vibration analysis for wind. Vibration analyses also were performed for the cantilevered seating deck to avoid the need for any costly supplemental vibration-reduction technology.★

Owner
Washington State Public Stadium Authority, Seattle
Paul Allen, Seahawks owner, Seattle

Architect
Ellerbe Becket Architects & Engineer, Kansas City, MO
LMN Architects, Seattle

Engineer
Magnusson Klemencic Associates, Seattle

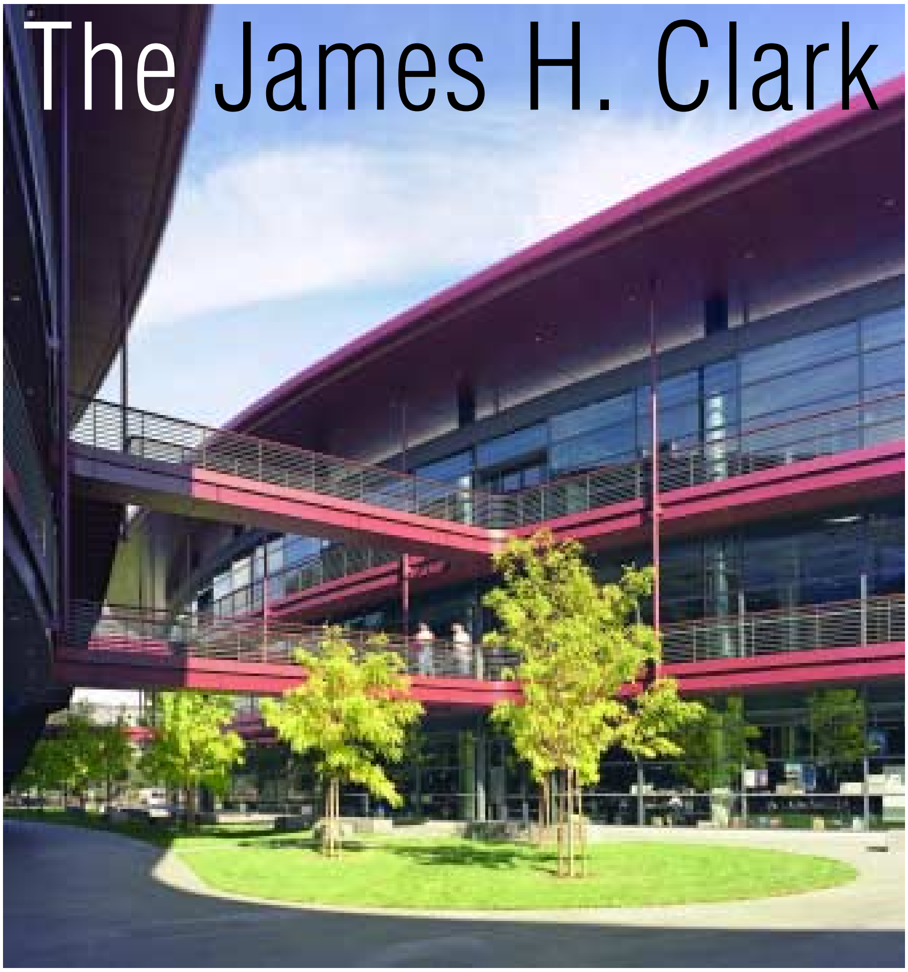
General Contractor
Turner Construction, Seattle

Engineering Software
SAP Non-Linear

Detailing Software
Tekla Xsteel

The James H. Clark Center

Stanford, CA



All photographs courtesy Paul Dileanis, Upshots Photography.

Owner
Stanford University, Stanford, CA

Architect
Foster and Partners, London (UK)
MBT Architecture, San Francisco

Structural Engineer
Middlebrook + Louie Structural Engineers, San Francisco

General Contractor
Hathaway-Dinwiddie, Santa Clara, CA

Fabricator
Gayle Manufacturing Company, Woodland, CA (AISC member)

Erectors
California Erectors, Bay Area Inc., Benicia, CA (NEA members)

Detailer
Naka Drafting, Whittier, CA
(NISD member)

Stanford University's new James H. Clark Center is a high-tech venture for advanced research in the life sciences. The 245,200-sq.-ft facility is home to "Bio-X," an ambitious program designed to dramatically improve the results of scientific research by fostering interdisciplinary collaboration between scientists from the Schools of Medicine, Engineering and Humanities & Sciences.

The Architecture

Clark Center occupies a 214′-by-421′ footprint on Stanford's campus. It features a 350′-long, uncovered central courtyard open to the north. Ground-level pedestrian ways to the east and west are located near the courtyard's south end. This geometry naturally divides the complex into three unequal, separate "pods" (East, West and South). The architects designed open labs on the curved, glazed perimeter adjacent walkways along the courtyard. This environment provides researchers a window to nature. It also allows passers-by to sense what is going on inside—an important programmatic requirement.

The complex is three stories, with a partial sub-level area. Exterior walkways, bridges and stairs provide a variety of circulation routes between the buildings. A continuous band of bull-nosed canopies slightly above roof level protect the walkways, shade the building's glass, and punctuate the vibrant architecture.

User Requirements

The design team was charged with satisfying several challenging requirements relating to vibration environment, large open spaces, lab flexibility and superior resistance to lateral (earthquake) forces.

Vibrations were of particular concern to the researchers. In terms of footfall excitation, the vibration consultant established the minimum goal to be 7,000 kips per in*sec., equating to a vibration amplitude not to exceed 1,800 μ-in/sec.

The design team also had to develop a solution for the desired high ceilings, stiff floors and dense distribution of mechanical, plumbing and other services. In addition, the design required adaptable floor plates, with high flexibility for future rearrangement of space.

Juror Comment

"The elegant architectural response to the clients brief has been equally reflected in the sublime steel design and detailing."

The Structure

Due to cost and construction-schedule considerations, structural steel was the best choice for the building's framing. Each pod has its own independent lateral force-resisting system. A system of walkways completely encircles the second and third levels, with pedestrian links designed with seismic/expansion joints to prevent the transfer of horizontal forces between pods.

The entire structure is developed on a 10′-6″ lab-plan module. Column spacing is dictated by the module, either 21′-0″ or 31′-6″. Columns, beams and girders are ordinary wide-flange sections. Nearly all floor and roof beams are 38″ deep to produce stiff floor framing that satisfies vibration requirements.

Lateral force resistance is provided by a dual system of Eccentrically Braced Frames (EBF) and Special Moment-Resisting Frames (SMRF).

Unique Structural Design Challenges

The building uses normal weight concrete (4½″) over 3″, 18-gauge composite steel deck, on W40x149 beams and girders. Beams and girders feature closely spaced 24″-diameter holes cut through their webs. These pierced spans allow passage of utilities/services, producing considerable savings in building height.

Calculated structural-system vibration characteristics are 7,770 kips per in*sec, with an amplitude of 1,550 μ-in per second. This performance was confirmed with finite-element analysis and validated by testing of an existing, similar structure.

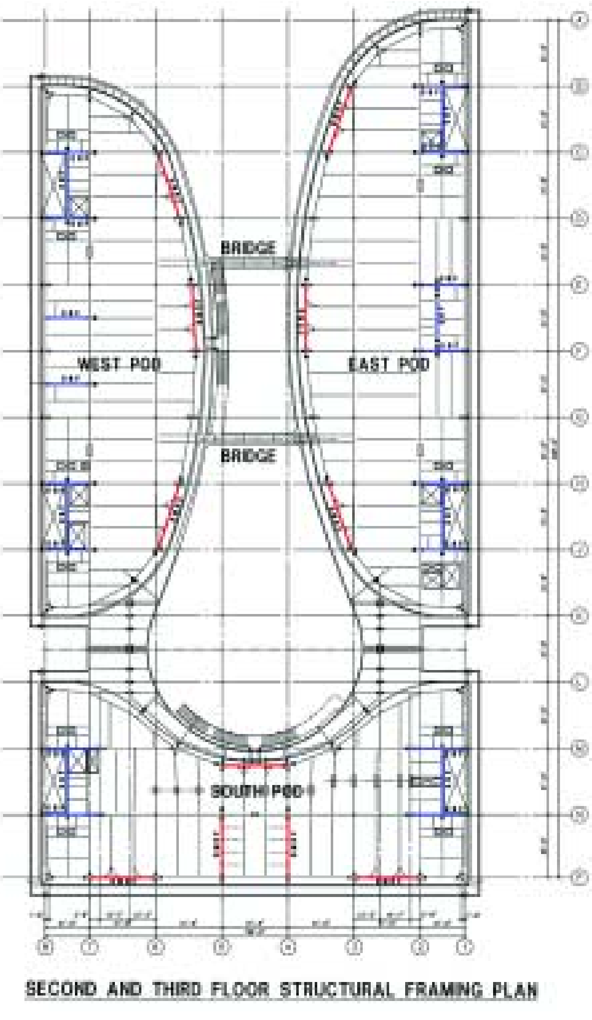
The SMRF beam-to-column connection (welded flange plate) was subjected to two full-scale tests. One failed at 5% rotation, the other was stopped at 4.5% rotation with capacity remaining, exceeding the 4% FEMA-350 test criteria.

Since walkways encompass the entire perimeter of the pods, live loads posed concerns for vibrations migrating into lab spaces. Cantilevered walkway beams were designed for required strength. After dead loads were in place, steel pipes were hung from roof outriggers and connected to the free ends of the cantilevers. The floor slabs of the walkways were separated at building lines. The vibration consultant confirmed the success of this "belt and suspenders" solution.

Outriggers support the roof canopy, as well as live loads from walkways and all loads from courtyard stairs. The 16′- and 20′-long cantilevers are stiff in spite of their 4′-8″ back spans.

Links between walkways include two narrow bridges over the courtyard, and two wide bridges from the south pod to east and west pods. Maximum spans exceed 60′ (with 18′ cantilevers), while depths are limited to the depth of walkway structure (18′-½″ for steel). The narrow courtyard bridges are on "conventional" slide bearings at one end. The wider bridges between pods feature innovative, mid-span seismic separations: the second- and third-floor structures are separated entirely at mid-span and are hung from "telescopic-seismic" beams at canopy level, supporting the entire three-story-wide bridge system. They are provided with a mid-span sliding joint, where a half-beam is allowed to move in and out (up to 15″) within a welded steel box fixed to another half-beam. Top and bottom "snug" slip bearings provide a couple to transfer bending moment (5,300′ kips) across the joint. Seismic separations are 10″ at the 2nd and 3rd floors, 15″ at the roof.

There are two types of exposed steel stairs: "exit stairs," along the exterior East and West elevations, and internal "courtyard stairs." The exit stairs are isolated from the building structure. The courtyard stairs run from ground level to the 3rd floor in continuous, curved ribbons along building lines. These stairs are hung from paired roof pipe hangers spaced 31′-6″. Inter-story stair drift concerns were solved by slip bearings at two floor levels, with fixed anchorage at a third. ★



SECOND AND THIRD FLOOR STRUCTURAL FRAMING PLAN

Gerald Ratner Athletics Center

Chicago

Photograph courtesy OWP/P

The University of Chicago Gerald Ratner Athletics Center is a $51 million state-of-the-art athletics facility with 150,000 sq. ft of health, fitness, and sporting activity space. The project is a "village" of athletic amenities that includes a competition gymnasium, an Olympic-sized natatorium, and other athletic spaces. The project features a first-of-its-kind asymmetrically supported cable-stayed structure that suspends S-shaped roofs over the large-volume gymnasium and natatorium spaces.

The primary structural challenge for this project was to develop the most efficient structural solution to fulfill the programmatic requirements for large volume column-free spaces on a restrictive site, while still meeting the university's design objectives and an aggressive construction schedule. Project requirements included the need for a "signature," architecturally expressive facility that would provide a flexible space to host athletic activities.

The cable-stayed structural solution gracefully supports the natatorium and gymnasium roofs with 10-story-tall masts. The elegant masts are among the tallest structures on campus, creating a campus landmark. The asymmetrical structure supports the roof loads from the "back" of the facility, allowing the community to experience the athletics center through large expanses of glass that abut the plaza and property line.

Juror Comment

"Elegantly detailed and fabricated—structurally ambitious and well considered."

The three-dimensional configuration of splayed cables at multiple levels makes this structure an engineering breakthrough. The structural solution adds a new classification of masted structures in the United States, providing a precedent for future structures with similar goals.

The structural solution for the gymnasium and natatorium space is a system of tapered composite masts, each supporting and stabilized by 15 splaying cables: 9 fore-stay cables and 6 back-stay cables, which in turn support the flattened S-shaped roof girders. The masts consist of three, 18"-diameter steel hollow structural sections (HSS) filled with high-strength concrete, arranged in a tapered, tied-column configuration. The non-linear analysis of the structure included a complex stability analysis for each of the masts, which are not symmetrically braced about their vertical axis, and are braced at multiple levels by tension-only elements of varying stiffness. Advanced dynamic and buckling analysis, including studies of several critical-mode shapes, were evaluated throughout the design process.

An innovative pumping technique was used to fill the masts with concrete.

Photo courtesy of OWP/P.

Each leg of the hollow mast is filled with 10,000 psi concrete, placed through "ports" located at the roof level. The cast-in-place concrete was allowed to free-fall 30′ to the base of the steel mast, and then was pumped up the remaining height of the in-place masts, past internal stiffeners located at the cable connections. This innovative approach to filling the masts reduced the possibilities of internal air pockets and voids. The horizontal HSS that tie the mast legs together were connected without gusset plates, transferring the cable forces through the masts in a clean and attractive fashion.

The use of multi-level splayed cables allowed the structural roof members to form a thin and uniformly curved roof plane only 33″ deep. The curved shallow members support a 7-1/2″ long-span metal roof deck that spans 25′ between the roof girders. The W33x169 girders are cold-bent to shape about their strong axis with reverse curves to multiple radii, and are suspended over the 160′ spans.

The curved roof planes are suspended from "full-lock" steel cables imported from Germany, which include three outer layers of interlocking Z-shaped wires specifically designed to minimize water infiltration and corrosion. Backstay cables stabilize the masts and transfer the roof load to massive concrete counterweights. The cable-stayed solution, along with a creative cable erection sequence that reduced the number of required shoring towers, reduced both construction time and cost of the overall project.

As with any cable-stayed structure, significant settlement of the masts could adversely affect cable tensions. This challenge was of particular significance on the Ratner Athletics Center given the soft-clay layer near the surface at the project site. To minimize and control settlement of the masts, ground improvements were necessary to transfer the large loads of the masts to a more suitable soil stratum. The improvements were achieved with triple-fluid jet grouting, an erosion-replacement grouting technique developed in Europe approximately 30 years ago, but used for the first time in Chicago on this project.

The project team was conscious of sustainable and environmental design opportunities. Environmental design considerations included the use of local suppliers and recycled materials. Structural steel, which is virtually 100% recycled material, was the primary structural building material. A fabricator located within 500 miles of the project site was awarded the project, minimizing transportation energy costs.

The Ratner Athletics Center makes a contribution to the advancement of structural engineering, and amplifies the role structural engineers play in the creation of innovative architecture. The building's structure is key to its architecture. The structural details are the architectural finishes, using circular base plates, acorn nuts, and sculpted gusset plates to create interest and aesthetic appeal. The Ratner Athletics Center offers a strong statement about the powerful architecture that can be created through mutual respect and collaborative efforts between architects and structural engineers. ★

Read more about the Ratner Center in the March 2004 issue of Modern Steel Construction *at www.modernsteel.com.*

Owner
University of Chicago

Design Architect
Cesar Pelli & Associates Inc., New Haven, CN

Architect of Record
OWP/P, Chicago

Structural Engineering Firm
OWP/P Structures, Chicago

General Contractor
Walsh Construction Company, Inc., Chicago

Steel Fabricator
LeJeune Steel Company, Minneapolis (AISC member)

Steel Erector
Danny's Construction Company, Inc., Gary, IN

Steel Detailer
Pacific Drafting, Inc., Carson, CA (AISC member)

Engineering Software
RISA 3-D
Robot Millennium

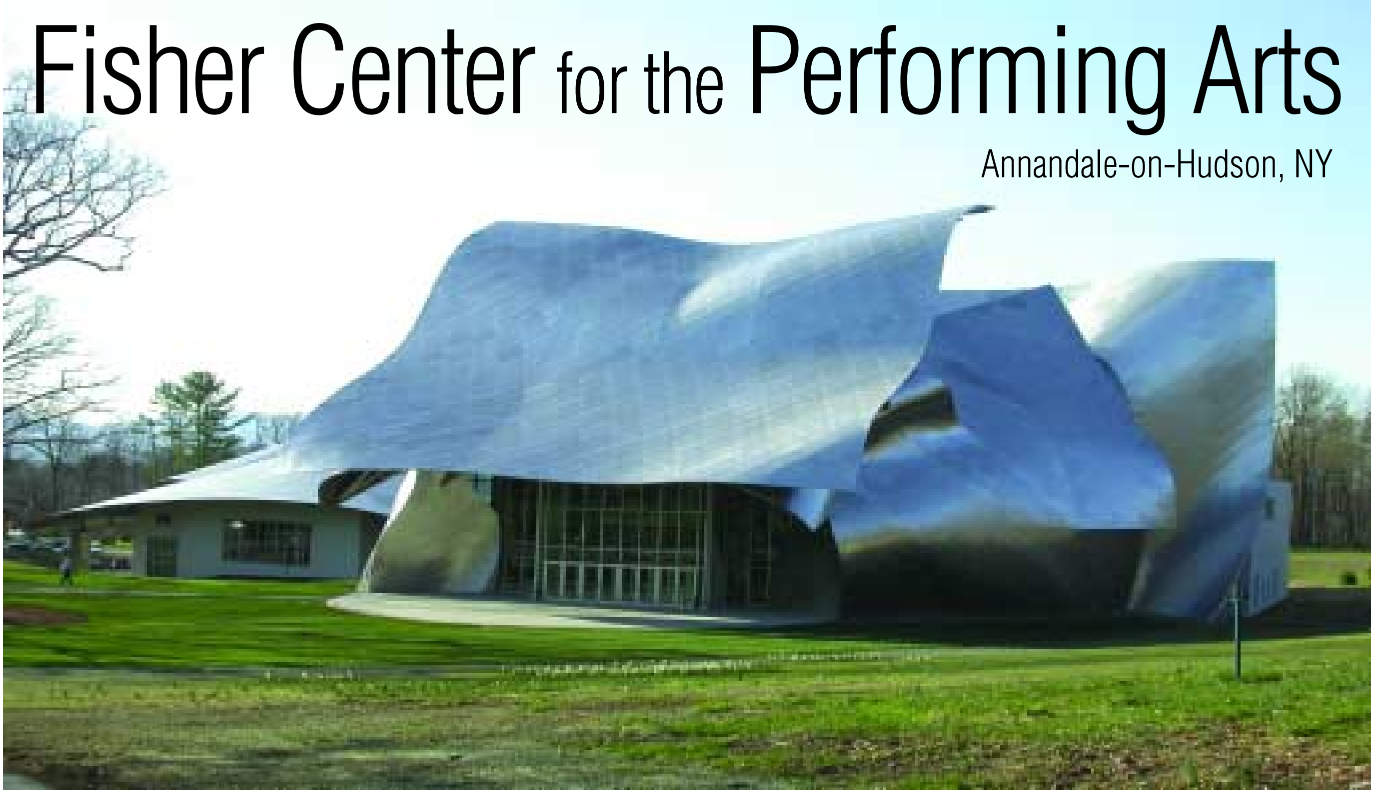
Detailing Software
SDS/2, AutoCAD

Steel Bending Services
Chicago Metal Rolled, Chicago

Photo courtesy of LeJeune Steel Company.

Fisher Center for the Performing Arts

Annandale-on-Hudson, NY



The $62-million Richard B. Fisher Center for the Performing Arts houses the campus's opera, dance, and orchestral productions as well as the school's theatrical teaching facilities. The 64,000 sq. ft complex comprises two distinct buildings that are linked by public assembly spaces and back-of-house infrastructure.

The design solution sought to satisfy the project's structural, aesthetic and programmatic requirements, and the final design is a harmonious blend of three distinct building technologies. To satisfy the acoustic requirements of the theatrical spaces, cast-in-place reinforced concrete was chosen for the main performance hall, and solidly grouted reinforced concrete masonry for the teaching facility. However, to meet the design's challenging long-span and aesthetic requirements, structural steel was used at roofs, at areas interconnecting the theaters and at other sculpted exterior surfaces. The complex coordination of these three structures demanded a variety of expertise and fastidious attention to detail.

The Fisher Center is notable for its innovative use of steel. The enclosure elements are the singular and most obvious steel element within the design. Soaring to heights of up to 100′ and cantilevering out to dramatic piercing knife-edge corners, steel was an ideal choice as it met both the aesthetic and structural requirements of the flowing Frank Gehry design. CATIA, an advanced three-dimensional modeling software, was used to define, dimension and coordinate the design and construction of this sculptural masterpiece. Three-dimensional modeling was an integral part of the design process from concept, to system interference checking, to shop drawings, and facilitated a seamless construction process.

Juror Comment

"Nicely executed design, detailing and erection to solve a complex shaped building."

The building's primary support steel is composed of rhythmic two-dimensional planar curved steel members, which are braced by web-like trusses of

Architect
Gehry Partners, LLP, Los Angeles

Structural Engineer
DeSimone Consulting Engineers, P.L.L.C., New York City

General Contractor
Daniel O'Connell's Sons, Holyoke, MA

Steel Fabricators
Berkshire Bridge & Iron Co., Inc., Dalton, MA (AISC member)

Columbia Wire & Iron Works, Portland, OR (AISC member)

Steel Detailer
Angle Detailing, Inc., Wilsonville, OR (AISC member)

Engineering Software
RISA-3D, ETABS, SAFE

straight, universally oriented diagonal elements. While there are now several completed Gehry projects featuring this type of undulating metal roof surface, the performing arts center is the first design to expose the supporting structural framework at the building's interior.

In addition to exposing the structure, interior finishes were deleted, leaving the ribbing of the metal panels exposed. To finish the surface, industrial stainless steel shingles were field applied to shop-built light-gage metal panels that clip to the structural steel elements. This skin met the design's industrial aesthetic requirements, and also met the design's cost and functional needs, providing both an economical finish grade solution and a functional external thermal and moisture envelope. At the more expansive volumes, the structural frame supporting the panels used an efficient truss work of steel members. The primary wide-flange shapes were curved to meet the undulating surface.

The lobby and front entrance sidewalls also feature exposed, custom-built steel shapes. These wide flange shapes were built-up from high strength structural plate, which had been CNC (computer numerically controlled) produced from computer data generated in CATIA. Thus, the resulting elements match and meet the shapes exactly. After the web CNC is cut, the flanges were CNC-bent on the weak axis (adjusting the curvature along each inch of length), and the resulting shapes were then assembled on a large setting bed and machine-welded at the interfaces. Many of the shapes were long and irregular, requiring that splices be made for trucking purposes. The bolted splices were all assembled in the shop to insure the tolerances of the bolt fit-up as well as continuity of the desired curvature.

The process of erecting the 60'- to 90'-long curved ribs was simplified by a few key design decisions. First, it was determined that the curved vertical elements would not act as columns. Placing load on a buckled shape substantially increases lateral deflection and member size, and necessitates fire-protecting the steel for the first 20', all of which would destroy the building's aesthetic lines. Cantilevering the roof steel from the cast-in-place walls allowed the design to avoid these difficulties. It also enabled the ribs to be thinned down. With the weight of the metal panels resting on the foundation walls and leaning against the diaphragm of the main roof through slotted connections that accommodate deflection, the ribs only needed to support their own weight.

At the Sosnoff Theater there are six different rib clusters that function together as a single braced unit. There are approximately 1000 brace-member connections, each with a unique vertical and horizontal angle. Setting the ribs individually would have required a complex and cumbersome system of temporary guying. To save time and cost, the permanent bracing was installed concurrently with each pair of ribs. To further simplify the process, a singular unique brace connection was designed to satisfy all details. The cut-to-length horizontal and diagonal steel angle braces span between ribs, pivoting on the single end hole to achieve the required spatial angle at the connection. The members are secured by male and female-ended D-shaped gusset plates above and below, and each has the ability to rotate independently to receive single-bolted diagonal members at different and unique angles. The design allowed for two adjacent ribs to be set with the bracing pivoted into place in a matter of minutes.

While the building's steel structure excels aesthetically and technologically, the process also proved cost and time effective. Change orders traditionally play a very important part within any design process, and are a direct reflection of the quality of the design documents. In the case of the Fisher Center, the design documents not only included the customary plans and specifications, but also the three-dimensional CATIA models. The fully coordinated CATIA models, which specifically addressed the building's steel components, made it possible for the construction team to better understand the building prior to construction commencement, resulting in substantial change-order savings. The clarity they provided enabled change orders to be held to a minimum, totaling only 1.3% of the contract value, a result which would be desirable for any project, let alone one with the theatrical and architectural complexity of the Fisher Center. ★

Read more about the Fisher Center for Performing Arts in the January 2004 issue of Modern Steel Construction *at* ***www.modernsteel.com****.*

EAE

Merit Award

Hobby Center for the Performing Arts

Houston

Photograph courtesy Frank White.

Juror Comment

"Beautiful interior spaces accomplished by good engineering."

Hobby Center for the Performing Arts grew out of Houston's Theatre Under The Stars (TUTS) need for an indoor performance space. Also home to the Houston Broadway Series, the 270,000-sq.-ft Hobby Center houses two performance spaces: Sarofim Hall, a 2,650-seat venue in which no seat is farther than 128′ from the stage; and Zilkha Hall, a 500-seat proscenium theater with natural acoustics for smaller companies. The complex also includes an administration building (The El Paso Center for Arts and Education); quarters for the Houston Music Hall Foundation; 3,800 sq. ft of rehearsal space for TUTS's Humphreys School of Musical Theatre; and 300-seat Artista restaurant.

The Hobby Center, designed by signature architect Robert A.M. Stern, is a world-class facility that advances Houston's commitment to outstanding architecture. The building features a dynamically sloped standing-seam metal roof with a gold soffit, identifying the facility as an important landmark in Houston's theater district. Other major building materials include limestone, brick, and painted steel columns. A glazed, 60′-high curtain wall provides views of downtown Houston's skyline and Tranquility Park. A terrace running the length of the Center offers an outside congregating area for theater-goers. A soaring covered walkway connects the main entrance plaza with a seven-level, 800-car parking garage.

The building complex is broken up into several distinct volumes, each representing one of the major program elements of the center. Two major pieces of public art are incorporated into the design of the project: a large mural by Sol Lewitt on the north wall of the Grand Lobby, and a bronze sculpture by Anthony Cragg in the plaza.

Engineering Challenges

Haynes Whaley Associates provided structural engineering services for Hobby Center, which opened in May 2002. The firm closely collaborated with all members of the project team to creatively integrate the structural design with the complex project requirements. The below-grade construction consisted of cast-in-place concrete. A composite steel structural system was used for the performance halls and other spaces above street level.

Ambitious architectural goals and close coordination between the theatrical, acoustical, mechanical, electrical, and plumbing systems, presented numerous challenges for the structural design.

Project Goals

Haynes Whaley Associates collaborated with the owner and architects to achieve the primary project goals:

1. Construct a state-of-the-art theater to meet modern theatrical requirements.
2. Construct a large performance hall that provides an intimate theatre experience.
3. Construct two performance halls on the same site that do not conflict acoustically. Acoustical isolation was achieved by dividing the structure into four segments.
4. Construct a grand lobby area that provides dramatic views of Hous-

Owner
Houston Music Hall Foundation, Houston

Architects
Robert A.M. Stern Architects, New York City
Morris Architects, Houston

Structural Engineer
Haynes Whaley Associates, Inc., Houston

General Contractor
Swinerton Builders, Houston

Steel Fabricator/Detailer
Safety Steel Service, Inc., Houston (AISC member)

Steel Erector
Peterson Beckner Industries, Houston (AISC and NEAA member)


Photograph courtesy Frank White.

ton's downtown skyline and Tranquility Park.

Complexity

The Hobby Center is one of the most complex structural steel buildings ever built in the City of Houston. The structure includes 5,800 tons of steel—enough steel for a 33-story building. The complex framing was dictated by the large volume spaces, the complex geometry, the ambitious architecture, the acoustical isolation of the two performance halls, and the need to make Sarofim Hall both large and intimate.

The cantilevered lobby balconies and the sloped-theater seating balconies are supported by a structural system embedded into the walls that separate the theater and lobby spaces. Steeply pitched theater balconies extend up to 37′ unsupported into Sarofim Hall, providing the required seating while maintaining an intimate setting between the upper level seats and the stage. The theatrical consultant required a minimum structural depth for the theater balconies in order to achieve uninterrupted sightlines for all theatre seats. A minimum overall balcony profile was achieved through the use of intricately laced structural framing techniques and details. This balcony framing approach resulted in minimal structural depths, while providing the necessary structural stiffness for audience comfort.

Prominent architectural features of the Hobby Center's front façade are large, sloping and vertical steel columns, which are integrated into the glass curtain wall. The steel columns provide gravity support for the roof and lateral support for the glass curtain wall. This structural support system provides unobstructed views of the Houston skyline from the Grand Lobby.

For the south-facing glass curtain wall, Robert A.M. Stern wanted a large expanse of glass and required the curtain-wall support system to "disappear." This was achieved by using narrow vertical support fins—4″-wide and 26″-deep solid steel members. These narrow members are hung in tension from the lobby roof structure to eliminate buckling effects.

The design of the lobby roof was challenging due to a wedge-shaped skylight, sloped in two directions, which interrupts the diaphragm of the roof system. The lobby roof trusses, which span through the skylight space, were designed with sufficient lateral stiffness to transfer the lobby-structure wind loads into the main building structure. ★

Swonder Ice Arena

Evansville, IN

All photographs © Fred Reaves, Image One Photography.

Juror Comment

"An impressive building for the cost. Simple and elegant steel detailing results in a practical solution meeting the owner's brief."

The Swonder Ice Arena is a simple building form that dynamically defines a massive space. The arena's roof curves across the width of the building along the line of a continuously curved W16 to create a sculptural shape. A cantilevered glass canopy supported from steel pipe columns and HSS beams welcomes visitors to the arena. The facility includes a 1000-seat ice rink, a 400-seat ice rink, indoor and outdoor skateboarding parks, a fitness area, a hanging walking/jogging track, a concession area and offices.

The W16 roof beam that forms the roof line extends from one end of the building to the other, with full-penetration welds at each connection. It also forms the top chord of a king-post truss over the 1000-seat ice rink; spans across the central core of the building; forms the top chord of another king-post truss over the 400-seat ice rink; and cantilevers over a low roof area, allowing clerestory windows between the two roof planes.

The roof beam was braced against twist at each end of the truss and at the centerline of each truss span, and was braced at the top flange by the roof deck. Designers used an LRFD design with the beam stability concepts developed by Joseph A. Yura, Ph. D. at the University of Texas, and determined the C_b value of the beam for the unbraced length of approximately 50′ on each half of the trusses.

Beam analysis was conducted using a three-dimensional model of the building to account for beam continuity and bracing, and the effect of horizontal forces acting simultaneously with the dead and live loads. A P-Δ analysis was used to include the effects of the deflection of the beam, and to satisfy the LRFD design. This was concern where the beam carries large axial forces as the top chord of the two king-post truss spans. The axial forces, together with the dead and live-load deflections, affect the moments in the top-chord beam and vary the C_b factor for each load case.

The roof was designed to support uplift wind forces. The uplift design case used the roof deck to brace the top flange of the beam, providing a conservative C_b value of 2.0 for the uniform-load design calculations, with the ends of the beam braced against twist.

The interior of the rink volumes were opened by establishing a 20′ spacing for

Owner
City of Evansville, IN

Architect/Structural Engineer
Jacobs Facilities, Inc., St. Louis

Architect
Edmund L. Hafer & Associates, P.C., Evansville, IN

General Contractor
Weddle Brothers Construction Company, Inc., Evansville, IN

Detailer
LJB, Inc., Dayton, OH
(AISC member)

Detailing Software
SDS/2

Engineering Software
RISA-3D

the roof trusses, and by keeping the lines of the trusses simple with a minimum number of members. An EPICORE roof-deck ceiling system spanning between trusses provided an appealing ceiling, supported the vertical loads, and provided the required diaphragm strength and stiffness.

The steel columns on one side of the 1000-seat ice rink were designed to lean towards the rink. The leaning columns impose horizontal forces on the building, as the horizontal component of the dead and live forces acting at the roof attempt to push the building to one side. These horizontal forces are resisted by diagonal bracing on each end of the building. The roof diaphragm, acting in concert with a horizontal truss located near the center of the building above the leaning columns, transfers the dead, live, wind, and seismic forces to the diagonal braces at the building sides. The horizontal roof truss can support the horizontal forces, but is too flexible to keep the horizontal deflection of the roof to an acceptable value. Instead, the stiffness and strength of the roof deck was used with the horizontal truss to reduce the deflection of the roof to a reasonable value, to provide some redundancy, and to support the trusses during construction.

The contractor first installed the horizontal truss and then installed the roof trusses from each side, working towards the building center, and completing the roof deck attachments between each set of trusses before placing the next truss. Until the roof deck was completed, it acted only to reduce differential horizontal deflections between trusses and to transfer horizontal forces back to the horizontal truss that spans between the two exterior lines of diagonal bracing. Once the roof deck was completed, the deck diaphragm and the horizontal truss acted together to support the remainder of the horizontal loads.

The walking and jogging track and a spotlight catwalk in the larger rink are hung from the roof structure, freeing the floor plan below. Despite the additional dead and live load demand that they place on the roof structure, they actually reduced net wind uplift near the peak of the roof, where the uplift forces generally would be higher. The continuous nature of the roof framing has the necessary stiffness to reduce vibration on the track to a comfortable level.

The project cost was just under $12 million, and the building was completed in 2002. ★

EAE

Merit Award

S.T. Dana Courtyard Infill

Ann Arbor, MI

Juror Comment

"A subtle architectural solution to enclose the central atrium has been elegantly achieved using simple structural steel detailing."

The University of Michigan's School of Natural Resources and Environment has a greatly expanded and newly refurbished home tucked behind its 1903 stone façade. The 11,000-sq.-ft expansion was accomplished entirely from within, by placing a series of mezzanines in an abandoned central courtyard and reclaiming the attic space that surrounded it. A new skylit roof encloses the entire structure, permitting daylight to enter courtyard-facing rooms as it has for 100 years. All this was accomplished while the building remained occupied, by using an innovative steel frame that extends up through the courtyard and covers the building like an umbrella.

The Samuel Trask Dana Building was built on the University of Michigan's Central Campus Diag as a medical school facility and has been home to the School of Natural Resources and Environment since 1961. The project was fast-tracked meet school-year scheduling requirements, and also focused on the responsible use of resources through the entire renovation.

The new steel frame permits the existing masonry bearing walls and foundations to carry their originally intended loads. The client required a frame that supported a massive skylight and left the existing building roof intact until the new roof was installed. The chosen aesthetic was a graceful framing system with exposed trusses that evoked iron-framed structures of the past. This frame was to rest on a series of courtyard columns, which, for both functional and aesthetic reasons, were not symmetrical about the axis of the courtyard.

In order to address issues of spatial aesthetics and plan asymmetry, SDI designed a truss with an arcing interior web. This evokes a traditional end-bearing gable truss, but in fact is a center-bearing truss which cantilevers outward from its bearing points in each direction. The cantilevering trusses form the "umbrella" which covers the courtyard footprint and beyond. In order to accommodate the asymmetry of the columns, short transfer beams were placed below pairs of truss panel points as a means of transferring forces from the

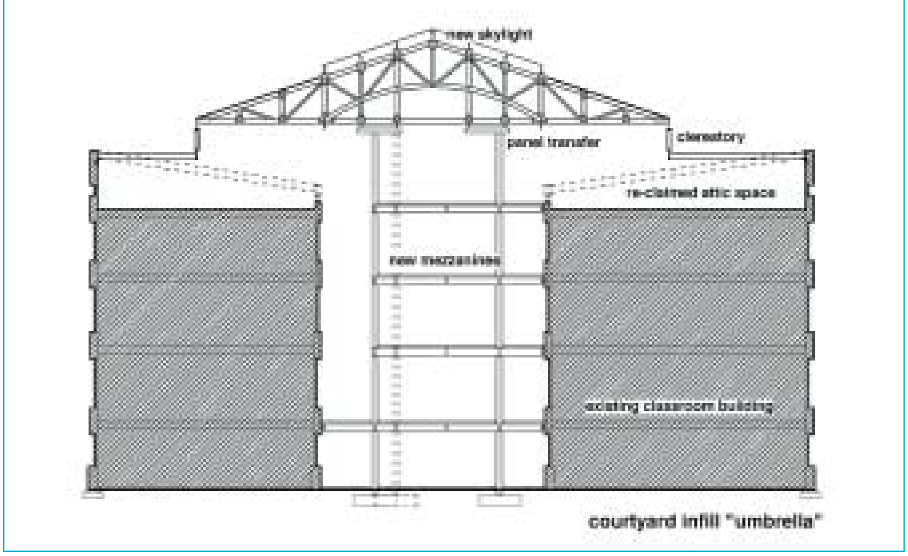
Owner
University of Michigan, School of Natural Resources and Environment Dana Building, Ann Arbor, MI

Structural Engineer
Structural Design Incorporated, Ann Arbor, MI

Architect
Phase I: University of Michigan, Architectural & Engineering Services, Ann Arbor, MI
Phase II: Quinn Evans, Washington, DC;
William McDonough & Partner, Washington, DC

Steel Fabricator, Detailer & Erector
Cadillac Iron, Inc., Oxford, MI (AISC member)

Structural Engineering Software
Multiframe3D



very regular truss geometry to the irregular column geometry below.

Suspended from the perimeter of the umbrella is a series of Vierendeel trusses which transfer lateral forces from a high roof to a low roof and create a clerestory window. All lateral forces in the roof are ultimately transferred as shear forces into the exterior parapets of the building, which were investigated to establish their capacity to resist the new lateral forces. No bearing walls or footings experience an increase in gravity loading. All new gravity loads are carried back to the "umbrella." ★

Schubert Club Band Shell

St. Paul, MN

Photograph courtesy Brian Gulick.

Juror Comment

"Refined section analysis, perfectly detailed, well-considered. Innovative design approach for lateral and refined loads. Good use of advanced computer modeling. Very elegant"

Raspberry Island, on the Mississippi River near Saint Paul, MN, is now home to an innovative steel structure that has helped reincorporate the island into the surrounding urban fabric. The Schubert Club Band Shell features a glass-covered anticlastic stainless steel lattice that uses an innovative system of offset pipes and rod diagonals that proved more economical than a more common welded grid.

The Schubert Club sponsors performing arts and an annual concert series, and for several years the club sought an outdoor location for performances. The club chose Raspberry Island because of its location and proximity to downtown.

Seasonal flooding precluded the use of closed shapes and required a robust base to resist impact from flood-borne debris. The Schubert Club hoped for an architecturally significant structure that would establish the island as vital public gathering ground.

Structural System

The structure includes a 25′-0″-wide anticlastic lattice that spans 50′-0″ to precast concrete piers and covers a wood-framed stage. Acid-etched glass is offset from and supported by the lattice. The piers are attached to below-grade pile-supported footings connected by three grade beams. The beams resist the lateral thrust of the lattice and support the stage.

The lattice surface is formed by rotating an upward-curving arc generator through a downward-curving arc. Angled planes form a quad-symmetric saddle shape. The abutments are tangent to the ends of the lattice and shaped as tapered extrusions of the arc generator. The lattice geometry allows repetition in glass sizes and detailing. It also allows all glass panels to be planer, avoiding the use of triangular or warped pieces of glass.

The lattice is made up of two layers of 1-$^{7}/_{8}$″-diameter pipes in opposing directions and a middle layer of $^{5}/_{16}$″-diameter rod diagonals. The top-layer pipes are spaced at 2′-0″ and span to the piers. These pipes are load-carrying elements and act as a series of joined arches. The bottom-layer pipes are spaced at 2′-6″ and span to the edge beams. Due to their high level of curvature, they act as secondary arches bracing the pipes in the top layer. Pipes in both layers have varying wall thickness: $^{3}/_{16}$″ in areas of low stress and $^{3}/_{8}$″ in areas of high stress.

The two layers are joined at crossings with 2″-by-1-$^{3}/_{8}$″-diameter posts. The posts are welded to the top-layer pipes

Owner
Saint Paul Parks and Recreation, Saint Paul, MN

Structural Engineer
Skidmore, Owings & Merrill LLP, Chicago

Design Consultant
TriPyramid Structures, Inc.

Architect
James Carpenter Design Associates, New York City

General Contractor
Meisinger Construction, Mendota Heights, MN

Structural Engineering Software
S-Frame version 5

and connected to the bottom-layer pipes by ½"-diameter through bolts concealed by the posts. A ¾"-long offset piece is welded to the top-layer pipes at each crossing. Each piece conceals the head of a through-bolt and is a base for a glass patch plate connection. The diagonals are 110 ksi stainless steel rods joined to machined split rings that fit around the posts. The diagonals are arranged so four diagonals form an X over four structural panels.

The lattice elements are connected to each pier by a continuous, curved, ½"-thick stainless steel plate. The plates were supplied to the precaster by the lattice fabricator to allow the lattice fabricator to control the positions of the connections relative to one another. Placing an embedment for each connection could have led to misaligned elements.

Structural Analysis

A shell formed by a continuous surface resists loads by in-plane shear and axial forces and low magnitude out-of-plane bending. The bandshell's lattice resists loads in a similar manner. Pipes develop in-plane axial and out-of-plane bending forces. Pipes and diagonals acting together resist shear.

The structure exhibits geometric non-linear behavior: loads magnify displacements and material non-linear behavior because the stainless steel is characterized by a non-linear stress-strain relationship. The analysis also included an evaluation of the structure's susceptibility to multi-panel buckling.

The structure was designed to limit-state theory. An elastoplastic variable secant modulus method was used to model material behavior. For a particular stress range, there was an associated secant modulus. With this method, high-stress regions were softened such that geometric stiffness was reduced and loads were redistributed. The method is similar to the one used to model the behavior of a variably cracked reinforced-concrete structure.

A non-linear iterative analysis method helped evaluate the structure. Combinations of snow loads and temperature differentials produced maximum stresses and buckling load ratios. Uniform snow loads were 40 psf; drifting snow loads approached 60 psf. Temperature differentials were considered for a 90-degree F range. The lowest buckling-load ratio for service loads was determined to be approximately 4. The maximum calculated deflection under service loads was 1½".★

Less than $10M

EAE

Merit Award

Reiman Gardens Conservatory Complex

Ames, IA

All photographs courtesy Assassi Productions.

Reiman Gardens Conservatory Complex is a signature architectural statement for the main entrance of Iowa State University. The mission was to create an exciting addition to an existing botanical garden. The new complex offers entomology and horticulture education to the staff, students, and the general public, while providing an entertaining experience. The University anticipates that that the new complex will draw visitors from across the state and the entire region.

A linear circulation spine ties the complex together like a main street: the restaurant, gift shop, Emerging Pupae display, and Learning Center. At the beginning and end of this street are two highlights—the Exotic Butterfly Flight House and the Conservatory. These are steel and glass greenhouses for plant displays which rotate on a three-month cycle.

In structure, the Flight House communicates its function with a delicate steel-and-glass form that emulates flight. The butterfly-shaped structure rests on two tapered piers, one concrete and one plate steel. Plate-steel thickness was limited to ½″ to allow cutting by a local fabricator's plasma cutter. The butterfly is composed of one large triangular truss and smaller steel pipe trusses. Support for curtain-wall, sprinkler piping, and exterior gutters are integrated into the exposed galvanized steel structure, creating a unified whole.

There is no diagonal bracing in the walls, but lateral forces at the roof are resisted by a steel-HSS-grid diaphragm and perimeter tension ring. The diaphragm is created by shop-fabricating small X-shaped sections of 1.5″ by 1.5″ round HSS with slots at each end. These slots drop onto smaller X-shaped connection plates built into the top chord of the trusses. The perimeter tension ring is also a 1.5″ by 1.5″ HSS, completing the 1.5″-thick diaphragm. Lateral forces (including torsion) are directed through the roof to the piers. Out-of-plane forces due to the folded-plate shape are resis-

Juror Comment

"Elegant, light steel structure emphasizing glass panels."

Owner
Iowa State University, Ames, IA

Architect
Architects Smith Metzger, Des Moines

Structural Engineer
Charles Saul Engineering, Des Moines

General Contractor
Story Construction, Ames, IA

Engineering Software
RISA 3-D

Detailing Software
AutoCAD

ted by the strong axis of the small trusses. Top-chord compression forces in the large truss cantilever through the truss depth and connect into the top of the piers. Connections of the small trusses to columns are designed to "disappear" by slotting the pipe columns into the truss webs.

The Conservatory structure is composed of small E-W pipe trusses and larger N-S pipe trusses. The structure steps down the existing grade by using the V-shaped small trusses, which are top-chord bearing at one end and bottom-chord bearing at the other. These rest on larger trusses with arched bottom chords, spanning from pier to pier. The arch creates a thinner section of truss at mid-span which seems counter-intuitive. However, this does give a lighter feel as the trusses "spring" from support to support. Stabilization of the smaller bottom-chord bearing trusses is hidden above the major trusses in the perpendicular directions, and aligns with the glass-roof supports. Galvanized steel sprinkler pipes, automated windows, automated shading, and steel cross-bracing are integrated into the roof structure. Shorter concrete piers and tall, tapered plate-steel columns resist lateral forces, eliminating the need for vertical cross bracing.

Considerable field welding and touch-up with a cold galvanizing compound performed well in the humid greenhouse environment. Small construction-related scratches in the surface of some members have exhibited minor rusting, but not at the connections. ★

Photographs courtesy FACE Design

Branford Point Residence

Branford, CT

Juror Comment

"The idea of drawing upon historic born construction techniques and adapting them to a residential steel system has been cleanly executed. The structure is refined, elegant...Innovation is highly evident and construction quality is first class."

The new 5,500-sq.-ft Branford Point Residence on the Connecticut shoreline is both progressive in its form yet sensitive to its local context. Inspiration for the design is drawn from local sources, like traditional New England timber-frame barn structures. The home is situated on the banks of a heavily trafficked river, and structural details of the nautical presence influence the building's architecture.

When designing the structure, some goals included:

- Achieve a generous volume of space, free of bearing walls and supporting columns, that allows a flexible floorplan.
- Create a low-maintenance structure that is protected from the elements of a varying climate.
- Efficiency in construction, limiting the amount of on-site costly framing time.
- Ability to be assembled in different configurations and applied to different programs.
- Merge with as many existing building techniques as possible.
- Incorporate pre-fabrication where possible
- Competitive in square foot cost.

The Solution

A post-tensioned steel-moment frame was chosen for the structure, since it could achieve column-free long spans, and was more environmentally responsible to use than heavy timber. The structure is composed of pre-manufactured connections and modified HSS sections, which were bolted together on the ground as "bents." They were then raised to form structural arches bolted to connections embedded in concrete foundation walls. These arches are braced with horizontal I-beams and fitted with connection points for the attachment of precut structural insulated panels (SIPs). The assembly of this superstructure took only seven days.

The stress-skin is becoming more common in construction for its super-insulative qualities, strength, and erection speed. The SIPS are 6″-thick sandwiches of high-density foam and recycled flake-

Architect
FACE Design, Brooklyn, NY

Structural Engineer
Robert Silman + Associates, New York City

General Contractor
Gary Frohlich Builders, Guilford, CT

Structural Engineering Software
RISA 3D

board, computer-milled to specification and delivered to site. Typically they are used either as an insulating skin over self-supporting timber frame, or at smaller scales as structural envelopes. When coupled with a steel frame and allowed to work structurally, large volumes can be contained efficiently. For this project, curved SIPs were developed for the first time, and were used for transitions at peaks and eaves. SIP Clips™ were developed to translate loads between frame and skin. The skinning of this envelope took four weeks.

The Home

The home is situated on a long narrow lot, and is accessed from an active street on its western side. The home was sited to orient views northerly to the picturesque riverscape while allowing natural light to filter from the South. Strategic carving of the envelope was studied digitally to maximize winter light, while providing shade in the heat of summer and to frame views of the river. A large sun-scoop sits on the roof, allowing reflected sun to spill down into the house and providing whole-house ventilation against the heat.

The main body of the house is one large volume. It contains a sizeable mezzanine housing two master suites and an overlooking library and lounge area. This mezzanine bridges a two-story vaulted great room to connect with a roof deck, and is accessed from an open steel and glass stair.

At ground level, the open plan is organized around the kitchen. Dining, living and lounge share the north face and river views, while pantry, office and bath reside in the south. A long circulation axis defines the halves and connects through the breezeway separation to the smaller wing to the East. This second body contains guest accommodations, a spa area and a garage with studio above.

The materials and finishes were influenced by the surrounding nautical environment. Patina, powder-coat and galvanization protect the steel, while IPE Ironwood, opalescent glass and natural stone provide warmth and tactility. ★