Innovative Design in Engineering and Architecture with Structural Steel

IDEAS² awards

2010 IDEAS² Awards Jury

Todd Alwood, LEED AP, Manager of Certification Business Development, AISC, Chicago

Mitchell A. Hirsch, AIA, Principal, Pelli Clarke Pelli Architects, New Haven, Conn.

Brad Lange, Pre-Construction Manager, Construction Products Distributors (a Weitz Company), Des Moines, Iowa

Mary Beth Malone, Partner, Elysian Hotels, Chicago

Jack Petersen, P.E., Principal; Martin/Martin, Inc., Lakewood, Colo.

Jennifer Richmond, Vice President of Project Management, Novel Iron Works, Inc., Greenland, N.H.

Tudor Van Hampton, Chicago Bureau Chief, *Engineering News Record* (*ENR*)

THE DESIGN AND CONSTRUCTION INDUSTRY recognizes the importance of teamwork, coordination, and collaboration in fostering successful construction projects today more than ever before. In support of this trend, AISC is proud to present the results of its annual IDEAS² awards competition. This program is designed to recognize all team members responsible for excellence and innovation in a project's use of structural steel.

Awards for each winning project were presented to the project team members involved in the design and construction of the structural framing system, including the architect, structural engineer of record, general contractor, detailer, fabricator, erector and owner.

New buildings, as well as renovation, retrofit, or expansion projects, were eligible. The projects also had to display, at a minimum, the following characteristics:

- ➜ A significant portion of the framing system must be wide-flange or hollow structural steel sections;
- ➜ Projects must have been completed between January 1, 2007 and December 31, 2009;
- ➜ Projects must be located in North America;
- ➜ Previous AISC IDEAS² or EAE award-winning projects were not eligible.

A panel of design and construction industry professionals judged the entries in three categories, according to their constructed values in U.S. dollars:

- ✓ Less than $15 million
- ✓ $15 million to $75 million
- ✓ Greater than $75 million

The judges considered each project's use of structural steel from both an architectural and structural engineering perspective, with an emphasis on:

- ➜ Creative solutions to the project's program requirements;
- ➜ Applications of innovative design approaches in areas such as connections, gravity systems, lateral load resisting systems, fire protection, and blast;
- ➜ The aesthetic and visual impact of the project, particularly in the coordination of structural steel elements with other materials;
- ➜ Innovative uses of architecturally exposed structural steel;
- ➜ Advances in the use of structural steel, either technically or in the architectural expression;
- ➜ The use of innovative design and construction methods such as 3D building models; interoperability; early integration of specialty contractors such as steel fabricators; alternative methods of project delivery; or other productivity enhancers.

Both national and merit honors were awarded. The jury also selected two projects for the Presidential Award of Excellence in recognition of distinguished structural engineering.

National Winner—Less than $15 Million

LAMAR CORPORATE HEADQUARTERS – HUDSONVILLE, MICH.

A construction company's vision to place its corporate offices into a cantilevered space above warehouse and shop space challenged the design team to create a satisfying work environment in an unconventional structural context. As designers sought to realize the owner's vision, guidelines were quickly established that would affect all aspects of the office design.

Two 16-ft-deep, 112-ft-long cantilevered trusses were envisioned that would support the office from a vertical circulation shaft. These trusses would architecturally define perimeter office units as well as primary traffic aisles. Understanding pedestrian traffic was key to project success because the associated vibration would be the governing consideration in the truss design. This brought the truss design into the realm of predicting not only building use and performance, but the subjective responses of the office occupants.

Early dynamic analysis suggested little difficulty with lateral and torsional motions, but vertical vibration presented some concern. The most reasonable truss designs would yield vertical mode vibration frequencies in a range approaching the frequency of rapid foot traffic. One solution would have been to add stiffness, but that also meant adding unwanted bulk to the members and connections, increasing both expense and visual obstructions.

The team chose as an alternative to design somewhat above the walking frequencies while also making provisions to install tuned mass dampers (TMDs), but only if the occupants ultimately decided they were necessary. In principle, no one on the team favored TMDs as an initial design solution, but there were recognized benefits in making provisions for them as a backup system. This saved the owner from having to use massive trusses while still ensuring that a satisfactory workspace would be achieved.

With this approach in mind, a preliminary design of TMDs was provided that promised to control uncomfortable vibration under worst-case projections. The office floor system was then designed to be framed with a pair of concealed chambers that would accommodate mounting TMDs to the bottom chords of the cantilever trusses.

Extensive in-place testing performed both during and after construction to determine actual vibration characteristics confirmed that the structure is providing comfortable office use. The building opened in July 2007, and because the TMD installation has not been required, the floor chambers built to house them remain unused. Even so, those chambers ultimately served the project well by allowing the design team to confidently work beyond the range of experience and certainty to create a workspace of unprecedented character.

The owner now enjoys a headquarters building that meets its functional needs, but also serves as a striking showcase of the firm's skills as builders and innovators.

Owner, Steel Erector and General Contractor
Lamar Construction Company, Hudsonville, Mich., (AISC and SEAA Member)

Architect
Integrated Architecture, Grand Rapids, Mich.

Structural Engineer
Structural Design Inc., Ann Arbor, Mich. (AISC Member)

Steel Detailer and Fabricator
Van Dellen Steel, Dutton, Mich. (AISC Member)

Consultant
Medhi Setareh, P.E., Ph.D., Virginia Tech, Blacksburg, Va. (AISC Member)

Photos by Paul Dannels/Structural Design Inc.

“This is not a building you could drive by without taking a second (**or third**) look.” —Jennifer Richmond

National Award—Less than $15 Million

FISHERS ISLAND RESIDENCE – FISHERS ISLAND, N.Y.

Fishers Island sits at the eastern end of Long Island, N.Y., approximately two miles off the southeastern coast of Connecticut. The island is home to approximately 300 permanent residents and a temporary population that grows to several thousand during summer weekends and holidays.

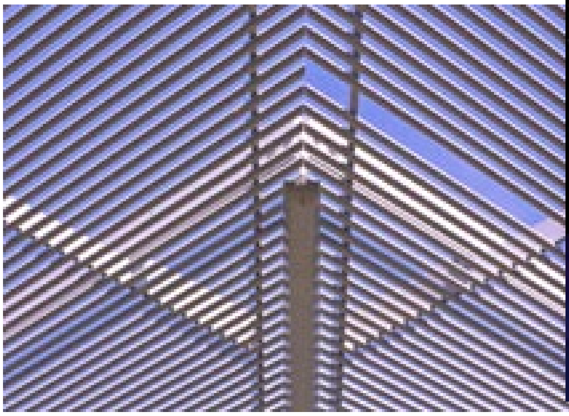
The design of the Fishers Island Residence is a response to the unique island setting and the personal interests of the client and primary resident. The 4,600 sq. ft house was envisioned as a permanent retreat for a client wishing to integrate day-to-day life with a passion for gardening and love of modern art, furniture and architecture. The architects designed an unmistakably modern house, with an open floor plan, minimal aesthetics, abundant use of glass and exposed steel, and a modular discipline that is equally organic in its relation to the surrounding garden and landscape. The successful connection between nature and the man-made structure is realized through the creative and expressive use of architecturally exposed structural steel.

The house is intended to simultaneously serve as a fully-functioning residence, a private museum for the owner to display a collection of art and furniture, and a permeable gateway into and through the surrounding garden. In an effort to create this uninterrupted connection, the architect used high-performance, insulated floor-to-ceiling glazing on all four external walls of the house. To minimize visual interruption in the glazing, the structural engineer designed slender 2.75-in. square, solid steel columns supporting W10 primary beams that span 29 ft and W4, L3x3 and L5x5 secondary steel beams. The wide-flange steel roof framing supports a 1.5-in. wide, rib-metal roof deck. Steel framing was essential for maintaining uninterrupted windows and allowing shallow roof spans.

The structural elements were carefully coordinated with the architectural expression, which greatly understates their relationship: the structural steel elements are the architecture. The exposed structural steel columns were engineered to be as small as structurally possible and designed to maintain a consistent, clean aesthetic throughout the house.

The aesthetic treatment of structural steel is prominently displayed by the 50 steel "trees" every 11-ft, 6-in. around the house. Each tree consists of a solid 3.25 by 3.25 in. steel cantilevered column, rigidly fixed at the base. A steel casting at the top of the column is connected with a single, concealed, high-strength bolt. The casting spreads into four diagonal cast

Photos by Scott Frances



> “A very **simple design** that lends itself very well to its surroundings.”
>
> —Brad Lange

“branch arms” at the top of each column that cantilever out approximately 8 ft from the columns.

A trellis of solid aluminum rods is supported at the tips of each branch arm. A secondary system of trellis framing spans above the aluminum rods, cantilevering an additional 3 ft beyond the edge of the branch arms. This secondary system is supported by individual, high-strength rods attached to an innovative concealed “tongue plate” connection detail. The concealed tongue plate and rod connection allows the trellis to float above the branch arms with almost no visible means of support. An adjustable and fully concealed steel puck-like connection at the base of each support rod permits adjustment of the trellis-to-branch arm connections.

The trellis, steel trees and branch arms are visually dramatic but also are essential to making the residence habitable. The canopies and trellis shield the full-height glass walls from direct overhead sunlight, dramatically reducing glare and light levels within the house. The steel trees also play an important role in the psychological transitioning between the outdoor natural realm, and the man-made environment of the interior.

To provide the unique architecture of this residence, the architect and engineer worked closely to develop connections that were structurally robust and visually pleasing, avoiding conventional structural steel connections that would have ruined the visual appearance. The use of architecturally exposed steel castings celebrates steel connections as sculptural objects, but required intense coordination among the architect, engineer and fabricator. All steel elements were designed per code to resist the harsh 120 mph costal winds and significant ice and snow loads.

Architect
Thomas Phifer & Partners, New York

Structural Engineer
Skidmore, Owings & Merrill, LLP, Chicago (AISC Member)

General Contractor
BD Remodeling & Restoration, Fishers Island, N.Y.

“It immediately **strikes a chord** with the viewer in the downtown park setting of Chicago.”
—Todd Alwood

Photos by George Lambros/Lambros Photography

Merit Award—Less than $15 Million

BURNHAM PAVILION – CHICAGO

The Burnham Pavilion was one of two temporary pavilions constructed in Chicago’s Millennium Park to celebrate the centennial of the Daniel Burnham and Edward Bennett Plan for Chicago. The project consisted of two large white planes, one of which served as an elevated walking surface, while the other was a widespread cantilevered roof. The two planes were joined by three large “scoops” that met with the roof to form openings in the roof plane, which frame predetermined views of the Chicago skyline.

Both the upper and lower planes used W18 sections on an axis skewed from orthogonal to accommodate the three large scoop openings. Each scoop housed three 8-in. A53 Grade B pipes inclined at an average angle of 48° from vertical to fit within the envelope of the of scoop. The entire pavilion structure was framed with 49 tons of structural steel and infilled with plywood ribs, had a 45 ft, 6 in. by 52 ft, 6 in. footprint and a maximum height of 19 ft, 6 in., with a total cost of roughly $1 million.

To achieve the unique form of the pavilion, three main structural issues required resolution. The first was the design of the dramatic 23-ft, 6-in. cantilevers. The cantilevers had backspans that were limited by the scoop openings, which could not be penetrated. Additionally, the roof was designed for a 90 mph wind load (20 psf, per the Chicago Building Code). An additional 15 psf roof live load was checked despite the fact that the roof was not intended to be accessible. This check proved to be justified when groups of people were seen climbing up the scoops while watching Fourth of July fireworks displays from the roof of the pavilion.

The second issue was that the curving form of the scoops did not allow for traditional vertical elements to support the roof structure, and thus a set of three sloping pipe columns was used in lieu of a vertical element. These three pipe columns all origi-

Photos by George Lambros/Lambros Photography

nated at a single spring point at the base, then splayed upward to connect to the skewed roof framing. Naturally, the basepoints received a large vertical reaction from the roof, as well as a high bending moment induced by the severely sloped columns. This large reaction was too great to be carried by the precast double tees that frame over a multi-track commuter railway yard below, thus becoming the third major structural issue to develop.

To solve this issue, a hexagonal steel grillage was provided directly below the spring point of the columns, rather than a direct support point. The grillage carried the load in bending across six horizontal "spokes" out to six support points, each of which saw a reaction small enough to be carried by the precast double tees. The analysis for the complex geometry was performed with finite element software using a linear elastic analysis.

Coordination among design architects, architects of record, and the fabricator was vital to keep the steel structure within the envelope of the pavilion's dually curving form. Due to the short time frame of the project, electronic 3D models had to be passed back and forth between offices with care and precision. Good communication among all parties and multiple software programs allowed detection of problem areas (cladding and structural interference) and ensured a smooth construction process.

The UNStudio Burnham Pavilion was completed on schedule and within budget, and opened to the public June 19, 2009.

Owner
Burnham Plan Centennial Committee, Chicago

Architect
UNStudio, Amsterdam

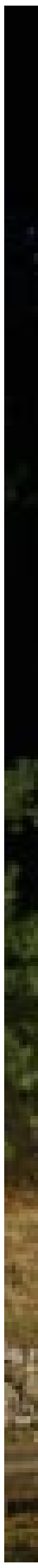
Associate Architect
Garofalo Architects Inc., Chicago

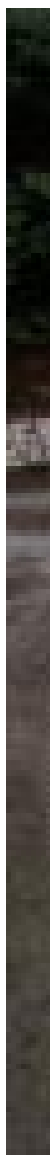
Structural Engineer
Rockey Structures, LLC, Oak Park, Ill.

General Contractor
Third Coast Construction, Chicago

Consultant
Dear Productions, Inc., Oak Park, Ill.

Structural Analysis Software
SAP2000





Merit Award—Less than $15 Million

STORAGE BARN – WASHINGTON, CONN.

> “This is a **beautiful and elegant** answer to the program.”
> —Mitchell Hirsch

Photos by Bo Crockett/Gray Organschi Architecture

For this structure, the architect envisioned a vertical and orderly method for storing landscape materials with minimal impact to the pondside site. The project design goals included electricity generation via a photovoltaic array on the roof, and a translucent skin to allow natural daylighting through the walls and roof. The 28 ft by 20 ft translucent structure also glows at night when interior lights are on.

The daylighting is accomplished with translucent insulated polycarbonate panels on the walls and transparent photovoltaic panels on the roof set atop light cowls. The basement contains mechanical, electrical and plumbing equipment for the solar array and for a geothermal heating system. The garage stores the forklift and other equipment.

As many as 114 custom steel pallets can be placed on the walls to hold stone tile, stone pavers, field stone, or firewood. The pallets reside on six tiers of steel brackets that cantilever from HSS steel columns.

The foundation and ground floor of the enclosed structure are, respectively, conventional cast-in-place concrete walls and a concrete slab on metal deck. The large and variable pallet loads and their large eccentricities created significant building torsional and sway forces as well as significant out-of-plane bending forces. The forces are resisted by the floor, roof, and four walls all structurally integrated into a rigid six-sided box.

The garage floor slab serves as the base of the box. The other five sides of the box are steel framed with moment frames along the four perimeter walls and a steel space frame roof. The moment frames are assembled from 16-ft-tall HSS6x6 columns and a wide-flange beam at the roof level. Diagonal braces were not used in the plane of the walls because they would obstruct the polycarbonate wall panels.

The lack of columns in the wall containing the full width door resulted in insufficient in-plane stiffness. Rather than increase column and roof beam sizes to compensate, additional stiffness was provided with vertical trusses, one on each side of the building. The trusses allow the columns elsewhere to remain small and consistent in size. The horizontal members of the vertical trusses also perform as a bracket for the pallets at each tier.

A designed and manufactured steel space frame was selected for the roof framing to satisfy three criteria. First, an eye-pleasing roof system was desired because it would be exposed to view. Second, in-plane strength and stiffness were necessary to resolve the building torsional forces and sway forces. And third, it does not obstruct light transmitting through the translucent roof surface.

The space frame was assembled on the ground into two pieces and then bolted to the perimeter roof beams to complete the rigid six-sided box. All structural steel was hot dipped galvanized. Slender steel outriggers were bolted to the top of the first bay along the perimeter of the space frame to support the very thin wood framed roof overhang. Wood 2x nailers were bolted to the top of the space frame at the nodes to fasten the plywood roof sheathing and the wood cowls that support the photovoltaic panels.

With 114 pallets, each potentially supporting stone material, there is seemingly an infinite number of possible pallet load arrangements to consider. Unbalanced loading can result in unusually large sway forces and large building torsional forces. The many possible pallet load arrangements were distilled down to those that would maximize building sway and torsion:

- A full complement of fully loaded pallets
- Load combinations with and without wind forces and snow loads
- An impact load due to the forklift dropping and lifting pallets

A 3D analysis model was created to test the strength and performance of the steel framed superstructure due to the various load combinations. The space frame roof was modeled as a rigid diaphragm with rigid links where it engages the roof beams. Then the output shear forces in the rigid links were transmitted to the space frame manufacturer for each load case use in designing the space frame and its connections.

The structural system derives its success from the use of simple components and its careful integration with the architectural design.

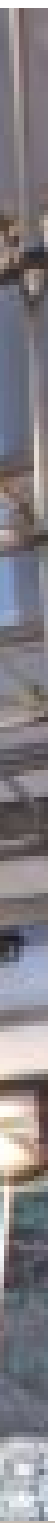
Architect
Gray Organschi Architecture, New Haven, Conn.

Structural Engineer
Edward Stanley Engineers, LLC, Guilford, Conn. (AISC Member)

Fabricator
Southington Metal Fabrications, Southington, Conn. (AISC Member)

General Contractor
Catalpa Management, Morris, Conn.

Structural Analysis Software
RISA-3D, Revit



National Award—$15 Million to $75 Million

CONTEMPORARY JEWISH MUSEUM – SAN FRANCISCO

The recently completed Contemporary Jewish Museum is one of the last pieces in the revitalization and transformation of the once decaying Yerba Buena district in downtown San Francisco. The bold and striking new 63,000-sq.-ft, $47.5 million museum building beautifully integrates modern materials and complex forms with the old Jesse Street Power Station, a national historic landmark designed by Willis Polk in 1907 during the "City Beautiful" movement. The historic features of the landmark substation, most notably its ornate brick and terra-cotta façade, steel trusses, crane and catwalk, were integrated into the building's structure.

The building's contemporary form was inspired by the Hebrew phrase *l'chaim* (to life!), which led to highly complex geometry and a very irregular structure. Given the complicated geometry, structural steel was the most appropriate and cost-effective framing system for the building.

The building is located in an area of high seismic activity. Resistance to earthquake loads is provided by steel braced frames. Although essentially a two-level structure, the highest point in this angular building rises almost 70 ft above the ground level. The complex geometry of the building blurs the lines between beams and columns, and which elements are resisting gravity loads and which are resisting lateral loads. Many columns are not vertical—some lean in two directions—and the braced frames carry not only the earthquake loads but also gravity loads.

Structural engineers built a 3D computer model of the building in order to perform detailed response spectrum dynamic analyses. Because the braced frames also carry gravity loads, seismic design is required to ensure nearly-elastic behavior for the maximum credible earthquake.

Designing and detailing the complex geometry posed a significant challenge, especially regarding connections. At numerous locations, as many as eight steel members come together at different angles and in different planes, requiring creativity and imagination in designing and drawing up the connections. Engineers drew as many as four views of key connections to convey the intent of the design. Because there was such large risk for unresolved issues and multiple change orders if the project had been bid and constructed using only 2D drawings, the details ultimately were drawn in 3D.

To overcome those concerns, the engineer recommended

"Tons of **curb appeal.**"

—Tudor Van Hampton

that the client retain the services of a steel detailer, Dowco Consultants, Vancouver, B.C., to develop a 3D model of the structure as the design proceeded. This approach, a precursor to current BIM practice, led to a highly interactive design process.

The engineer provided AutoCAD files of design drawings to Dowco as they were developed. Dowco used that information to prepare its 3D model and sent that information back to the engineer for review and updating its drawings. Using this process enabled the team to identify and resolve a host of conflicts and potential problems. Making the model available to steel bidders led to reduced uncertainties, and, consequently, tighter bids.

The general contractor and the steel detailing, fabrication and erection team were brought on board early in the design phase, allowing for creative and practical solutions and close collaboration. That led to a project that was successfully completed within time and budget with only minor changes. The museum opened to wide acclaim in June 2008.

OLMM was awarded the 2009 Outstanding Structural Engineering Project Award for the California region by ASCE for this project.

Owner
Contemporary Jewish Museum – San Francisco

Architect
Studio Daniel Libeskind, New York

Associate Architect
WRNS Studio, San Francisco

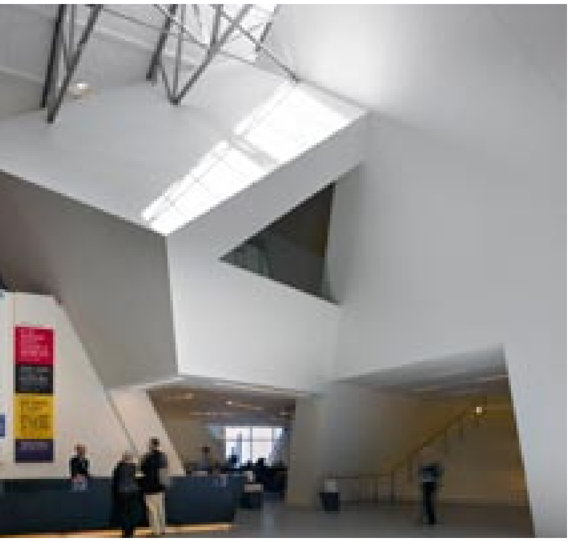
Structural Engineer
OLMM Consulting Engineers, Oakland, Calif.

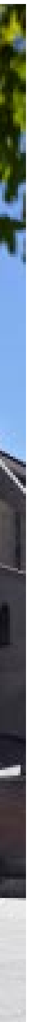
Steel Erector
Olson Steel, San Leandro, Calif. (IMPACT Member)

General Contractor
Plant Construction Co., San Francisco

Consultant
ARUP, San Francisco (AISC Member)

Structural Analysis Software
SAP2000, TEKLA Structures





National Award—$15 Million to $75 Million

DEE AND CHARLES WYLY THEATRE – DALLAS

The Dee and Charles Wyly Theatre features an unprecedented vertical organization that completely rethinks the traditional approach to theater design. For centuries, traditional theaters have been horizontally oriented around the performance chamber, with "front of house" and "back of house" areas flanking either side and a fly tower above.

The Wyly architecture team instead envisioned a transparent four-sided performance zone at ground level that would blur the lines between inside and out, actor and observer, in a literal interpretation of the world as a stage. To create this vision on a small site within a tight budget, the architectural and structural teams pulled apart each individual theater program element; carefully examined usage, size, and adjacency requirements; then reassembled the pieces into an intricate vertical structural stack, with "back of house" becoming "above house" and "front of house" (including the lobby) becoming "below house." This vertical rearrangement produced the desired 27-ft-high, fully transparent, structure-free, four-sided, ground-level performance zone, but demanded the invention of a one-of-a-kind structural steel system.

To create the most flexible performance space ever, the building itself had to be able to move, adapt, and evolve. Through the application of advanced technologies—both newly developed and borrowed from other industries—the Wyly is a miracle of moving steel parts, driven by engineering innovation. The audience chamber moves up, down, in, and out to create an unlimited number of performance configurations: proscenium, thrust, arena, traverse, studio theater, flat floor, bipolar, and sandwich have been identified so far.

The 27-ft-high proscenium arch—unmovable in most theaters—retracts straight up into an enlarged "super-fly" area. Three-tiered steel balcony units—the largest weighing 120 tons—also move up and down, adding 180 additional seats upon demand then "disappearing" when not needed. The balcony units lower from/lift into the super-fly area, can adjust horizontally up to 6 ft based on stage configuration, and carry their own drawbridge floor and access stair units. A combination of moveable seating wagons and nine moveable platforms rise, fall, and rotate to accommodate stage arrangement or produce a totally flat, open floor. The orchestra pit rises and retracts below the performance floor into the three-level below-house area. Even the walls move, with two 10-ft-wide floor-to-ceiling glass panels pivoting to the outside. The resulting "building machine" offers complete reconfigurability and true performance freedom. No other venue in the world can host an open-to-the-outdoors, flat-floor event in the afternoon, and an intimate stage performance only hours later.

Photo by Theo Raijmakers

> "A great demonstration of what a steel frame can do that **no other material** could accomplish."
> —Jack Petersen

Looking at the structural frame developed for the Wyly, it is clear that a traditional structural system could not have met the project's unique and complex program goals. The requirements were strict: No structure could be inserted in the 90-ft by 90-ft ground-floor performance area; no structure could interfere with the negotiated above-house program areas; and only a minimal amount of structure could interrupt the ground-level transparency zone.

The answer, pure but complex, is a unique "global frame" consisting of six perimeter columns, four of which incline dramatically and asymmetrically to touch down in precisely predetermined locations. A three-story-high steel belt truss augmented by smaller interior steel trusses fill out the global frame, minimizing vertical height while supporting a puzzle-piece assemblage of rooms so complex and interlocking that only one floor at the top of the belt truss is contiguous.

The vertical positioning of the belt truss optimizes the strength of that one contiguous floor, while intricate positioning of the belt truss/sloped column intersections supports 44-ft corner cantilevers and 90-ft clear spans at ground level, preserving views and column-free performance areas. Opposing building forces are addressed using strategic inclines rather than traditional (and intrusive) vertical braced elements, with dual-duty columns resisting gravity and wind loads. This minimalist yet highly effective structural solution produces a ground-floor performance area

Photo by Theo Raijmakers

Photo by Iwan Baan Photography

with no interior columns and accomplishes the architect's goal of blurring the lines between audience and stage.

The steel belt truss encompassing Levels 4 through 7 supports loads so heavy that each of the building's four truss faces relies on the connectivity and continuity of the other three faces for stability. In other words, no single truss face is stable on its own. As a result, complex construction sequencing analyses were used to determine the ideal erection sequence. Ultimately, six temporary erection columns supported the truss until the four truss faces were joined and successfully functioning as a cohesive 3D unit.

Owner
AT&T Performing Arts Center, Dallas

Architect of Record
Kendall/Heaton Associates, Houston

Design Architect
REX/OMA, New York

Structural Engineer
Magnusson Klemencic Associates, Seattle (AISC Member)

Steel Fabricator
W&W Steel, Oklahoma City (AISC Member)

Steel Erector
Bosworth Steel Erectors, Dallas (AISC, TAUC, and SEAA Member)

General Contractor
McCarthy, Dallas

Consultant
KFC Engineering, Oklahoma City

National Award—$15 Million to $75 Million

ARKANSAS STUDIES INSTITUTE – LITTLE ROCK, ARK.

The Arkansas Studies Institute, a unique partnership between a metropolitan library and a state university, is a repository for 10 million historic documents and the papers of seven Arkansas governors, including President William Jefferson Clinton.

Located in a thriving entertainment district near the Clinton Presidential Library, the design combines significant but neglected buildings from the 1880s (heavy timber) and 1910s (concrete) with a new technologically expressive steel archive addition, creating a pedestrian focused, iconic gateway to the public library campus and the face of Arkansas history. Public spaces—galleries, a café, and a museum—enliven streetscape storefronts, while a great research hall encompasses the entire second floor of the 1914 building.

Because the existing structures could not support the weight capacity needed for the archive collection, a new addition on a 50-ft-wide lot previously used for parking was planned to house three full floors of compact shelving above an open, glass-wrapped "soft story" gallery at street level. Steel was the obvious choice because it provided the required free spans and offered architecturally expressive truss options for the interior gallery. The juxtaposition of heavy document storage above light, open galleries creates an instantly identifiable image for the Arkansas Studies Institute.

In formulating the structural concept, designers studied how the existing buildings' structures were left exposed, expressing the construction methods of the different centuries in which each was built. The beauty of these structures is in the simple elegance of constructing just what is needed, meaning that all structural systems for this building should be celebrated as part of telling an honest story—the story of the state's construction history. The goal was set to minimize applied ornamentation normally found in a library building, and instead to show the functional detailing of the steel in a beautiful way.

The design philosophy is based literally on the book—a physical container of information, with pages flowing into a site-sensitive, physical narrative of the building's function. Multiple curving glass walls hang lightly off of the wide-flange and HSS frame of the new addition's main façade, representing pages of an open book where patrons literally walk through the pages of history, from new to historic spaces.

Between buildings, a thin atrium pulls the new steel structure away to protect the old, stretching the building's length and flooding all levels with light—a key sustainable strategy. Suspended bridges span the gap between new and old, connecting architectural centuries. This four-story atrium acts as a vertical gallery to tell the state's story. Steel-framed handrails mimic filmstrips through the height of the space, providing locations for 100 historic images from the archives in glass panels.

The steel bridges are suspended from a trussed interior frame, hinged at the base in a drawbridge-like fashion, and incorporate wood bridge decks recycled from a bridge in the present governor's hometown. Document storage displayed through the atrium's glass walls expresses that knowledge is within reach.

To avoid a true atrium designation, a concealed steel fire shutter divides the space into two vertical zones, which is a

"The exposed steel in this building is a great example of how structural steel can be used as an **aesthetic feature**."
—Brad Lange

photos by Timothy Hursley

unique and less costly solution that allowed the structural steel to be left exposed. The expressive bridge-like frame of the new archive's structure acts as the lateral bracing for the building. The structure was not only left exposed, but the steel deck was left unpainted. Light testing proved this solution equal to paint, and much more honest—raw history on display.

The curving west structure bends back to miss the site's only mature tree, while creating a reading lawn at the gallery steps, achieving a symbiotic relationship between the man-made and nature. The new addition's structure is actually on the outside of the building façade. This creates an expressive grid that acts as a shaded porch, inviting all at the main pedestrian street to be drawn into the new gallery, as well as around the corner to the main library entrance on the next block. Extended steel beams at western and southern floor edges are capped with galvanized steel grates to expand sun protection and lighten the edges. The west façade's pin-mounted vertical frosted glass fins control sun exposure while displaying historic faces of Arkansas life, like large bookmarks in time.

The copper-clad steel entrance idea came during project research, as the designer was using an old worn leather book, studying not only the content but the way the book moved as the pages turned. Taking cues from this written medium, the copper entrance acts as an abstract book cover, pulled away from the building as a double wall, diffusing the setting sun's light and heat in the entrance atrium beyond. And like a leather book cover, with its binding exposed to the intersection, the copper will age over time.

Locally sourced materials tell the story of the state's industries, exceeding sustainable requirements for distance to site and recycled content. The steel structure offered manufacturing within the state and 97% recycled content, adding to the fact that steel is the dominate construction material of our time and place. Aluminum curtain wall and skin, making up over 90% of the exterior, was fabricated just blocks away at a major glazing company.

The Arkansas Studies Institute weaves history, research, the citizenry, and a restored streetscape together, healing a gaping wound in the urban fabric, while serving as a beacon of knowledge.

Owner
Central Arkansas Library System, Little Rock, Ark.

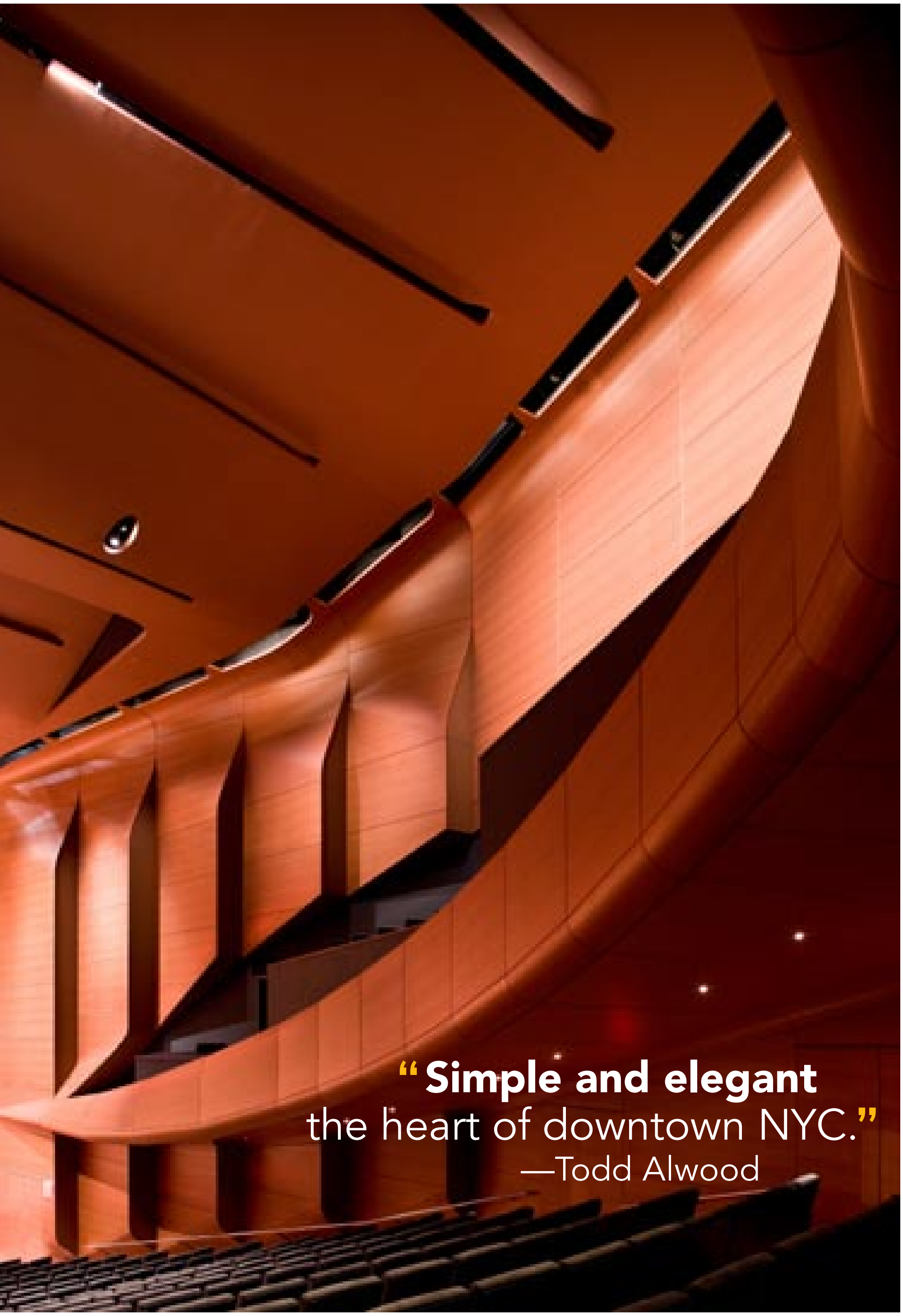
Architect
Polk Stanley Wilcox Architects, Little Rock, Ark.

Structural Engineer
Kenneth Jones and Associates, Inc., Little Rock, Ark. (AISC Member)

General Contractor
East Harding, Inc., Little Rock, Ark.

National Award—Greater than $75 Million

LINCOLN CENTER JUILLIARD SCHOOL, ALICE TULLY HALL – NEW YORK



"Simple and elegant the heart of downtown NYC."
—Todd Alwood

The transformation of the Juilliard School and Alice Tully Hall opens the existing building to the neighborhood making it more accessible to the public. The project adds approximately 150,000 sq. ft of new space, and at the same time upgrades interior finishes, building services and life safety systems in the existing building.

All of the construction work on this project had to be coordinated with the ongoing operation of the school, activities on the campus, and performance and event schedules for Alice Tully Hall, which was dark for only one season. During the five years of design and construction, the project team created and coordinated multiple packages of documents corresponding to the logistical challenges and sequencing of the work. Temporary spaces were created to replace functions impacted by construction. Construction managers, design team and owner's project managers exercised a high level of oversight during construction to minimize conflicts and mitigate unforeseen field conditions.

This challenge was magnified by a desire for the highest quality levels in selection of materials and craftsmanship. Most of the interior finishes and exterior curtain walls are one-of-a-kind systems, specifically created for this project. The interior wall panels of Alice Tully Hall are a unique laminate of super thin wood veneer on resin panels. The eastern façade of the Juilliard School is a highly customized, highly translucent glass wall to open the building to the public.

Complex structural elements, duct runs, curtain walls and wall panels were designed and built using 3D modeling technologies, which the engineers and architects also used for interdisciplinary coordination.

The structure of Alice Tully Hall uses a smart, cost efficient partial-box-in-box construction in combination with rail isolation on the subway lines to isolate the hall from the vibrations of the 7th Avenue Subway. In addition, new HVAC systems lower the background noise imposed on the space. A new high-performance inner liner is acoustically engineered to distribute sound evenly throughout the house. Thin layers of Moabe veneer laminated to three-dimensionally curved resin panels are tailored around all existing hall features, eliminating "visual noise" that distracts the audience from the performance.

The improved facilities will allow Lincoln Center to continue its tradition in offering world-class performances and education to local, national and international audiences. With its innovative use of new materials, unique space generating structure, interface of new and old, logistical and schedule challenges, the project pushed New York's design and contractor community to the boundaries of construction technologies and what could be built, setting a new standard for future buildings to come in this city.

The expansion of the Juilliard School of Music above Alice Tully Hall is facilitated by a number of parallel, west-east running, story-high, steel mega-trusses, which cantilever over a new public plaza and create a unique architectural space. The mega-trusses are made up of W14 sections weighing up to 398 lb/ft. In a complex layering of additional secondary trusses and tertiary beams floor plates are made up of concrete on metal decking and built up or hung down from the mega-trusses.

The mega-trusses have a cantilever to backspan ratio of 3 to 2 and a structural depth of 13 ft, 5 in. The backspan is socketed into the existing columns of the existing building. Existing columns and footings required reinforcement to allow for additional load imposed by the expansion. The columns on the other support points for the trusses define the exterior envelope of the new lobby. A new single layer, flat cable curtain wall separates the new lobby from the exterior plaza. The cable net imposes large tensile forces onto the steel structure and onto the foundations to limit deflections for the glass panels.

The mega-trusses were prefabricated by the steel supplier and feature stiffened, welded connections at each of the truss node points. The welded connections, which are free of gusset plates, allow for the passage of the building services systems. Top and bottom chords were spliced at quarter points, diagonals are spliced at their mid points, allowing for the assembly of the trusses on site.

Construction started in spring of 2007 and lasted through February 2009. The project opened on schedule in February 2009 earning unique critical acclaim in the press and in the construction industry.

Owner
Lincoln Center Development Project, New York

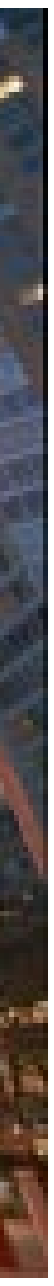
Architect
Diller Scofidio + Renfro, New York

Associate Architect
FXFowle, New York

Structural Engineer
ARUP, New York (AISC Member)

General Contractor
Turner Construction Company, New York (IMPACT Member)

Photos by Iwan Baan/ Iwan Baan Photography



National Award—Greater than $75 Million

BANK OF AMERICA TOWER AT BRYANT PARK–NEW YORK

Rising a majestic 1,200 ft above the streets below, the Bank of America Tower at One Bryant Park joins the ranks of New York City's architectural masterpieces. Owned jointly by The Durst Organization and Bank of America, this building showcases the results of innovative architectural and engineering design, which facilitated the creation of the tower's magnificent crystalline shape.

The beauty of the tower, however, is only one of its contributions to the city. Perhaps even more important, this new tower likely will become the first high-rise building in the world to earn a platinum LEED certification from the U.S. Green Building Council. To earn this notable designation, building designers incorporated not only green construction practices but also an array of sustainable technologies, such as a graywater collection system, thermal storage and a cogeneration power plant, enabling it to consume less water and use less energy than a conventional office tower.

The building was constructed using approximately 25,000 tons of structural steel—with a recycled content of at least 75%—and 45% granulated blast furnace slag (GBFS) substituted for cement in the concrete. The design also specified many recycled and local materials, avoided materials with volatile organic compounds, and minimized the generation of construction debris.

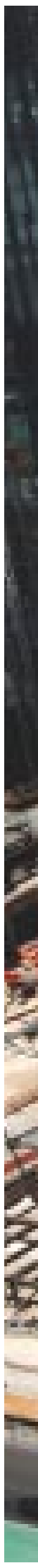
A project of this magnitude required collaboration among all parties. Coordinating the work of numerous firms is difficult under the best of circumstances, but the project's location less than a block from Times Square, in the center of midtown Manhattan, made the process substantially more challenging.

The building includes 2.1 million sq. ft of office and trading space spread over 51 occupied floors. There are three expansive cellars beneath the building—the deepest is 60 ft below ground level—and four mechanical floors at the top. The peak of the angled screen wall reaches a height of 945 ft while the 300-ft architectural spire tops out at 1,200 ft above the sidewalk. At a point about one third of the way up, the corners of the building start to taper gradually inward, giving the building its distinctive appearance.

Because steel erection was scheduled to precede placement of the core walls, the core framing was designed as a temporary structure, which only had to support 12 floors of its own weight before being encased in concrete. The core itself was framed with columns and beams, just as it would be for a conventional steel building, but the framing was much lighter. To accommodate the outer elements of the self-climbing formwork system, temporary slots were framed in the structural steel surrounding the core.

Cantilevered screen walls that extend up to 60 ft above the roof preserve the little space left at the top of the building for mechanical equipment. The supporting structural steel, which is visible from outside the building, was given a clean, simple look by using bolted sleeve

"It is a **distinctive** piece of architecture while still working toward **sustainability**."
—Jack Petersen



connections. The larger tubes fit snugly over the smaller tubes and give the joints the appearance of being fully welded. The purely aesthetic architectural spire continues the taper of the faceted walls to a single point at its tip. Although originally envisioned as a single lattice of welded steel pipes, the spire was fabricated in a series of shop-welded subassemblies that were bolted together in place.

As a New York City landmark, the 80-ft-wide, 50-ft-high brick and terra cotta façade of the historic Henry Miller's Theater had to be preserved. The interior of the theater, however, was not protected, which meant that it could be demolished and reconstructed. Before demolition could begin, though, the façade was stabilized by using an external steel framework that cantilevered from the sidewalk. The façade occurs at the deepest portion of the building's foundation, so careful underpinning and a rock shelf were used to support it.

Reconstruction of the theater posed challenges as well. The auditorium size and location required the transfer of several of the podium columns. To eliminate the need for shoring and reduce overall erection time, steel plate girders instead of trusses were used to make the transfer. One-piece plate girders would have been too heavy and too deep to lift over the existing façade so each plate girder was built up from three 7-ft-deep full-length sections. Making that substitution allowed steel erection over the theater to proceed without an interruption to install temporary supports. At the exterior of the building, using a steel vierendeel truss minimized obstruction of the view from the windows.

Double lines of steel framing and columns located on the sides and back of the auditorium create a 4-in.-wide joint to acoustically isolate the theater from the building that surrounds it. Independent bracing on the east and west sides of the auditorium resists lateral loads longitudinally. Transversely, bearing pads bridge the joint—with no significant loss of acoustic isolation—to transfer lateral loads to the building's diaphragms and shear walls.

In addition to their functional requirements, the owners desired a building that would reflect and embody the principles of sustainable development and yet still be economical to construct and operate. Many systems and strategies were considered but only approaches that represented a reasonable return on investment were pursued and implemented. Although adding green technologies and construction practices marginally increased the project budget, the expected savings in energy and water will continue to benefit the environment long after the additional initial construction costs have been offset.

Photos by Ray Jackson/Bernstein Associates

Owner
The Durst Organization, New York

Architect
Cook+Fox Architects LLP, New York

Associate Architect
Adamson Associates Architects, Toronto

Structural Engineer
Severud Associates, New York (AISC Member)

Steel Detailer and Fabricator
Owen Steel Company, Inc. Columbia, S.C. (AISC and SEAA Member)

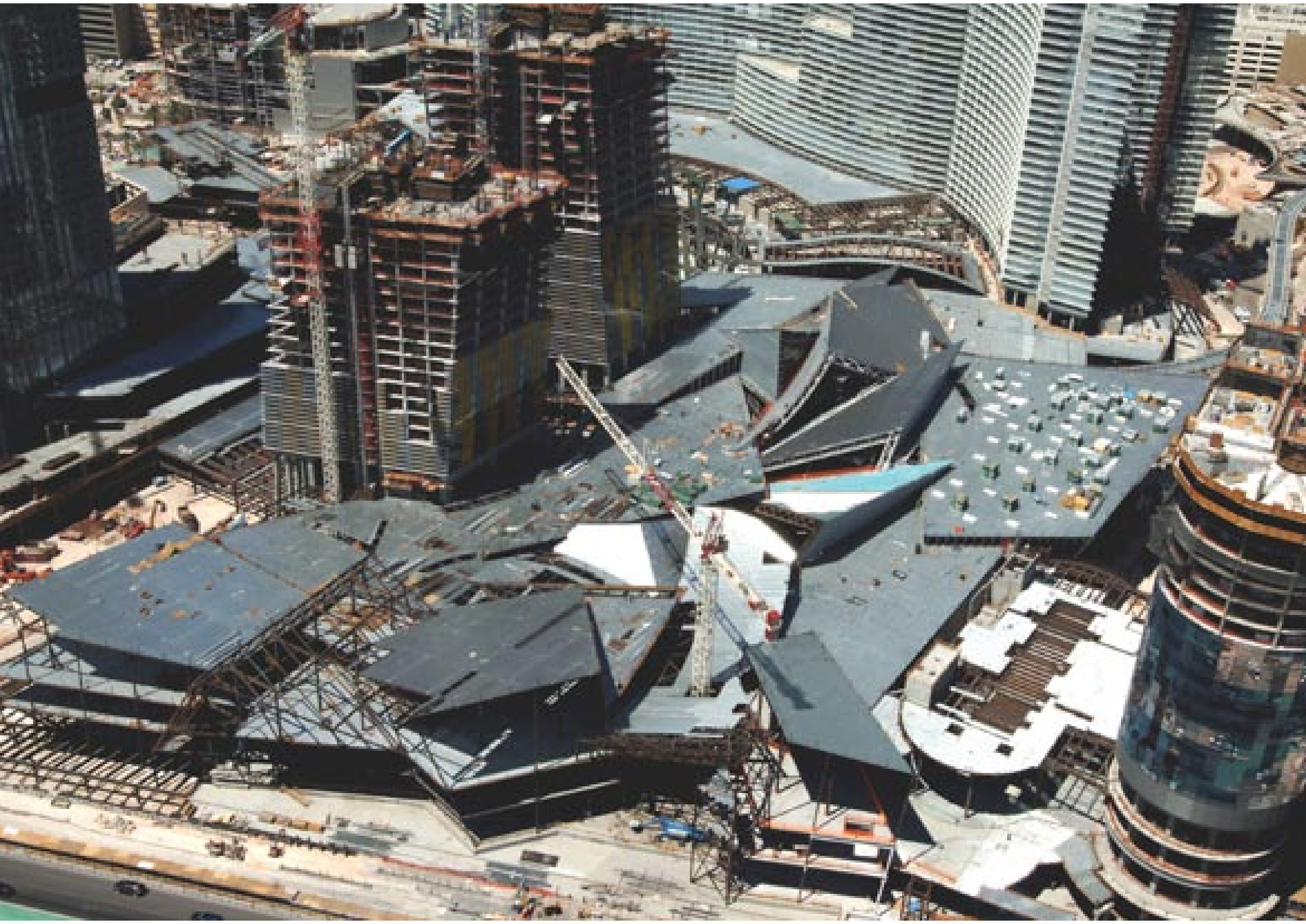
Steel Erector
Cornell and Company, Inc., Westville, N.J. (AISC and IMPACT Member)

General Contractor
Tishman Construction Corp., New York (AISC Member)

Consultant
Jaros Baum & Bolles, New York

Merit Award—Greater than $75 Million

CRYSTALS AT CITYCENTER – LAS VEGAS



Crystals is the centerpiece of CityCenter, an $8.5-billion Las Vegas urban development retail and entertainment district designed by eight renowned architects. The 665,000-sq.-ft facility includes a below-grade garage, two levels of retail and a one-of-a-kind roof, which is the most complex and unique design within CityCenter.

The roof actually consists of 19 separate pieces—13 planar roofs and six dramatically sloped arcade roofs—each erected with numerous leaning columns, curving trusses and straight members that do not line up with any other piece of steel. The six arcade roofs were the most complex element of Crystals.

Crystals' roof has no right angles, does not follow a pattern or have any repetitive placements of steel. All of the six arcade roofs are designed at different angles to connect with the 13 planar roofs. The six arcade roofs converge at the apex of the facility with the planar roofs on the side. The arcade roofs are covered in glass to create a massive skylight to illuminate the building's interior, hence the name Crystals.

The challenge for the design-assist team was to figure out how to build this complex facility on schedule and budget. The design-assist portion of the project alone took 12 months of working through mathematical equations and strategic planning to devise a 3D model, which ended up including 16,455 pieces.

While the connections of the lower floors were standard, the roof system required distinctive solutions at almost every end point. More than 500 unique sketches were generated for the roof connections, each of which had to be manually modeled, as no single macro could accommodate these variations.

More than 90% of the 52,766 steel connections are bolted. Some trusses and columns have as many as 15 connections. When bolting was not an option, joints were welded on site. The banana truss, which measures 6 ft deep and almost 200 ft long, slopes to the apex of the facility and was among the most critical welding tasks on the entire project. Crews hung the banana truss with two cranes while they welded it in three different places.

Three-dimensional modeling was paramount to the project, including creation of BIM models for various trades and consultants. Without the software, constructing Crystals would not have been possible; manually drawing the extremely complex geometry would have been cost-prohibitive. Using a 3D system, however, there were almost no detailing-related errors.

CityCenter's master plan dictated that construction begin at

> "This design shows that, **when using steel**, the only limit to what can be created is the **imagination**."
> —Jennifer Richmond

Photo by Schuff Steel Company

Photo by MGM Mirage

Photo by Schuff Steel Company

the west side of the project and work toward Las Vegas Boulevard. That meant erection started at the highest point of the roof, but had to strategically "jump" around to ensure stability of all the leaning trusses and columns.

The team first determined where each of the 80 major trusses went and from there worked backward to resolve what each truss would support, and what would support it. With thousands of massive beams, 160 trusses and 69 pipe columns literally cutting through one another and leaning at extreme angles—as much as 40°—every piece of steel required calculations to test for load capacity, fabrication and constructability.

The fabricator used 14 fabrication shops to meet the Crystals' accelerated deadline. Fabrication started in January 2006 and was completed in March 2008 for the base contract. Over that two-year period, 1,433 trucks were required to deliver the 13,900 tons of structural steel. The result is a stunning structure that also is Gold LEED certified by the USGBC.

Owner
MGM Mirage, Las Vegas

Architect
Studio Daniel Libeskind, New York

Associate Architect – Architect of Record
Adamson Associates, Toronto

Structural Engineer
Halcrow Yolles, Las Vegas (AISC Member)

Steel Detailer
BDS Steel Detailers, Tempe, Ariz./South Brisbane, Australia (AISC Member)

Steel Fabricator and Erector
Schuff Steel Co., Phoenix (AISC, IMPACT, and SEAA Member)

General Contractor
Perini Building Co., Henderson, Nev. (AISC Member)

Consultant
Gensler – Architect of Record, Las Vegas

Structural Software
Tekla Structures, Revit, AutoCAD

> "A project such as this allows the industry to move from **research** to **practice**."
>
> —Jack Petersen

President's Award of Excellence in Engineering

L.A. LIVE – LOS ANGELES

Photo by Nabih Youssef Associates

The Los Angeles Convention Center Hotel and Condominium (LACCH) tower encompasses more than 1.2 million sq. ft of floor space comprising a 26-story low-rise portion combined with a 55-story portion that reaches more than 650 ft above street level. The project carried a $1 billion development cost, and is the focal point of a large integrated development stretching across two city blocks.

The tower is composed of 26 floors of hotel rooms in each of the wings, topped by 29 additional levels of condominiums in the taller tower. The tower includes a tapered floor plate that expands and contracts to suit the requirements of the occupancy type. The design features high ceilings with low floor-to-floor heights while minimizing the curtain wall, and maximizes sellable floor space by minimizing circulation paths and back-of-house spaces.

The structural system is an optimized direct fit into the architectural shape, maximizing program efficiency and seismic performance. The system consists of unstiffened thin steel plate walls (⅜-in. to ¼-in. thick) within fully welded WUF-W moment frames that act as boundary members.

The walls consist of infill plates that buckle in shear and form a diagonal tension field to resist lateral loads, resulting in substantial post-buckling ductility. As there was no centralized core of walls and the floorplan for the lower 26 stories formed a "T" shape, the steel plates were used to "tune" the stiffness of the separate wings.

The boundary element frames included composite concrete-filled box columns in order to achieve a higher axial capacity at minimal premium. Where possible, the steel columns on the tower exterior slope from one floor to the next to match the architectural profiles and maintain a constant slab edge distance while minimizing disruption to useable floor space.

Outriggers at mid-height and the roof level further control building drift, effectively reducing the aspect ratio of the tower from 20:1 to 10:1. Buckling restrained braces, some with design capacities as great as 2,200 kips, were at the time of design the largest that had been tested in the world, and are used as fuse elements to control the maximum forces that the outrigger trusses can impose upon the surrounding elements.

The design consisted of more than 18,000 tons of fabricated steel, with 12,000 structural members. These include 612 box columns, 670 wide-flange columns, 8,200 beams, 795 shear wall assemblies, 12 trusses, and 11 buckling-restrained braces. The low self-weight of the steel plate shear walls, compared to an equivalent reinforced concrete shear wall, reduced both gravity loads and the seismic demands that the structure is required to resist. In addition, replacing concrete walls approximately 36 in. thick with ⅜-in. steel walls plates allows for more programmable space.

Given that the tower was the first of its type in California, and did not fit within the realm of typical codified design, it was designed using the code-accepted alternative of performance-based design, with extensive nonlinear analysis for confirmation of design. Throughout the project designers worked closely with the general contractor and steel subcontractors, resulting in the tower's substantial completion only one year after the start of erection. The use of steel members allowed for a more reliable, consistent product than concrete, while also permitting multiple tiers of construction to coexist over different levels of the tower, greatly increasing the efficiency of assembly.

Owner
AEG (Anschultz Entertainment Group), Los Angeles

Architect
Gensler, Santa Monica, Calif.

Structural Engineer
Nabih Youssef Associates, Los Angeles (AISC Member)

Steel Detailer
Herrick Corporation, Stockton, Calif. (AISC Member)

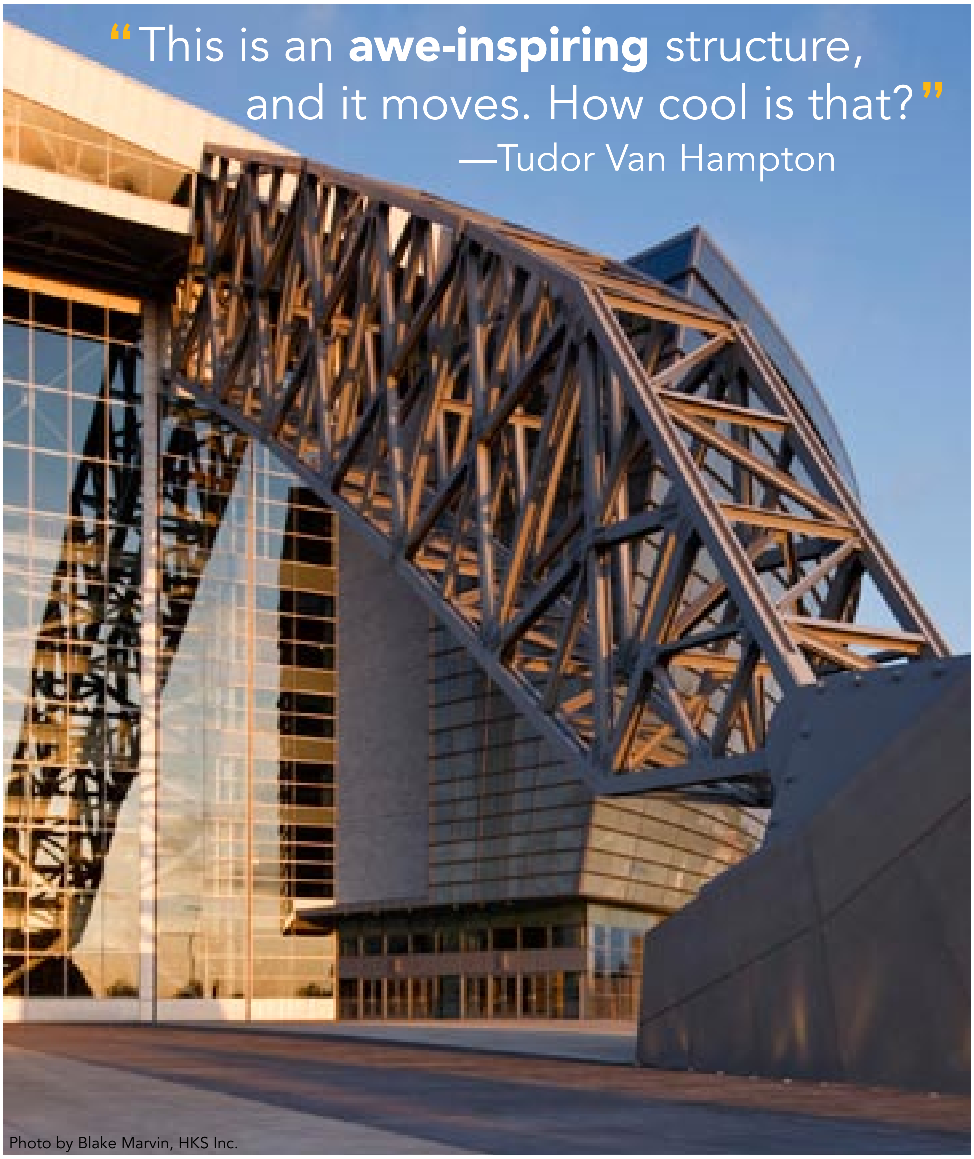
Steel Fabricator and Erector
Herrick Corporation, Stockton, Calif. (AISC Member)

Roller/Bender
Albina Pipe Bending Company, Inc., Tualatin, Ore. (AISC Member)

General Contractor
Webcor Builders, Los Angeles

President's Award of Excellence in Engineering

COWBOYS STADIUM – DALLAS



> "This is an **awe-inspiring** structure, and it moves. How cool is that?"
> —Tudor Van Hampton

Photo by Blake Marvin, HKS Inc.

Cowboys Stadium, home of the NFL's Dallas Cowboys, puts the power of structural steel on world display. With its June 2009 opening, the monumental $1.15 billion, 80,000-seat (100,000-person capacity), three million sq. ft, retractable roof superstructure established numerous world and industry firsts, including:

- The world's longest single-span roof structure (1,225 ft, fully exposed to view).
- The world's largest roof-hung HD video display board (25,000 sq. ft).
- The world's largest operable glass doors (180 ft wide by 120 ft high).
- Operable roof panels that traverse the steepest incline of any North American retractable stadium.
- A first-of-its-kind rack-and-pinion roof drive system.
- One of the world's first installations of a Teflon (PTFE)-coated fiberglass tensile membrane with a photo catalytic titanium dioxide coating that breaks down dirt through sunlight, actually cleaning the roof automatically.

The structure will serve as a regional economic engine that will pay for itself as much as 16 times over during the next 30 years, while enhancing the value of one of the world's premier sports franchises.

The owner's goals were clearly defined: create a new standard that changes the game-day experience and to which all future sports and entertainment venues will be compared. Architectural design began with establishing the team's brand equity. The shape of the opening in the roof, the star on the field, the international identity of the team, and the realization that the Cowboys have always been a team of "firsts" all greatly influenced the design of the new venue.

The stadium's two large plazas extend from the end zones, framed by monumental steel arches that support the roof, provide a venue to host game day activities and serve as a pathway into the stadium. Patrons are greeted by the world's largest operable doors that open to reveal the dynamic view into the seating bowl. The retractable roof was configured to preserve the Cowboys' global brand by recalling the trademark "hole-in-the-roof design" of their former home, Texas Stadium.

To support the new stadium's 660,800-sq.-ft domed roof, engineers designed a pair of architecturally exposed steel arch box trusses that span a world record-breaking 1,225 ft—the entire length of the stadium—creating an iconic steel form that has been incorporated prominently into the new Cowboys Stadium brand. The apex of the 1,025-ft-radius arches is 292 ft above the field. Engineers capitalized on this height to optimize the design, limiting the total depth of the arch trusses to just 35 ft and the final total roof structural steel tonnage to just 14,100 tons, which was within 0.7% of the early roof structural steel bid issue.

An approximate 25% increase in yield strength and subsequent steel tonnage savings were realized by minimizing the arch truss chord slenderness ratios for compression. Using ASTM A913 Grade 65 high-strength steel shapes rather than conventional ASTM A992 Grade 50 shapes optimized the design and saved the owner more than $3.5 million.

Numerous truss configurations were examined before a quadrangular Warren configuration was selected to create a distinctive argyle pattern of web members along each vertical side. This repeating X configuration reduced the stress on the chord members and allowed the use of standard rolled shapes, reducing expense and construction time.

Another crucial structural challenge was to economically resist the 19 million lb of thrust from the nearly quarter-mile arch span. To resolve this monumental-scale force, the engineering team de-

Photo by DVDesign

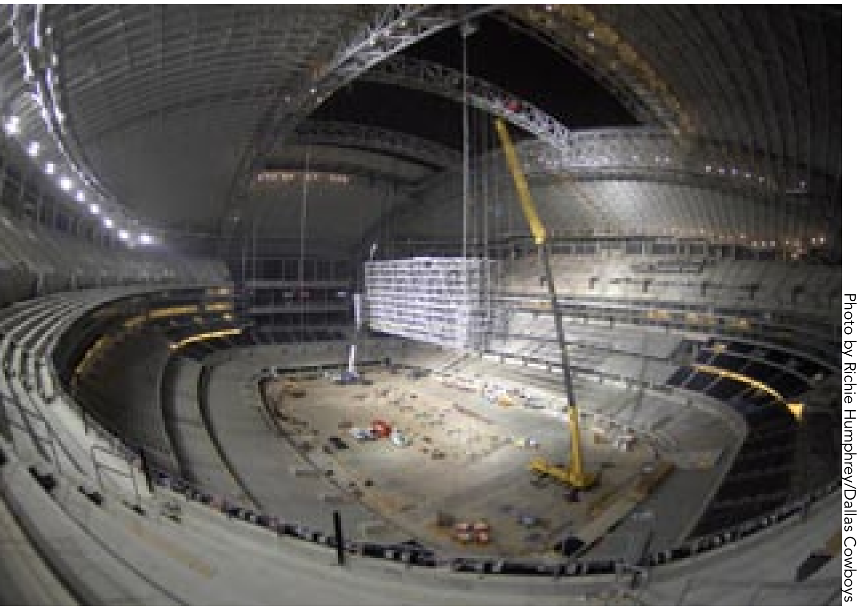


Photo by Richie Humphrey/Dallas Cowboys

Photo by Blake Marvin, HKS Inc.

signed a 64,000-lb cast solid-steel (ASTM A148) pin bearing assembly at each end of each arch truss, which is anchored atop the concrete abutment.

The two retractable roof panels, each measuring 290 ft by 220 ft, travel along the length of the arches to abut at the 50-yard line. The panels are clad with a translucent Teflon (PTFE)-coated fiberglass tensile membrane. This is the first application of a rack-and-pinion retractable roof drive system in North America and the largest and steepest (24°) such roof application in the world. Each of the 128, 7.5 horsepower motors efficiently powers a pinion that eases the operable panels up and down 328 ft of toothed steel rack, permanently attached to the arch trusses.

The steel arch trusses hold aloft the $40 million, 25,000-sq.-ft, center-hung, 1.2-million-lb high-definition video board, plus support 200,000 lb of show-rigging loads that can be placed in dozens of configurations. Extending from nearly 20-yard line to 20-yard line, the display is supported off a 10-level steel frame structure suspended with 16, 1½-in.-diameter wire ropes with a computer-controlled vertical lift system.

The project team's integrated project delivery approach addressed numerous design, fabrication and erection issues including roof geometry, connection design, erection sequencing, thermal movements, tolerances, and fit-up.

Owner
Dallas Cowboys Football Club, Irving, Texas

Architect
HKS, Inc., Dallas (AISC Member)

Structural Engineer
Walter P Moore, Dallas (AISC Member)

Steel Fabricator
W&W Steel Company, Oklahoma City (AISC Member)

Roller/Bender
Max Weiss Company, Milwaukee (AISC Member)

Steel Erector
Derr Steel Erection Co., Euless, Texas (AISC and IMPACT Member)

General Contractor
Manhattan Construction Co., Dallas

Consultant
Uni-Systems, LLC, Minneapolis (AISC and IMPACT Member)