$100M OR GREATER

NATIONAL WINNER

Seattle Central Library

Seattle

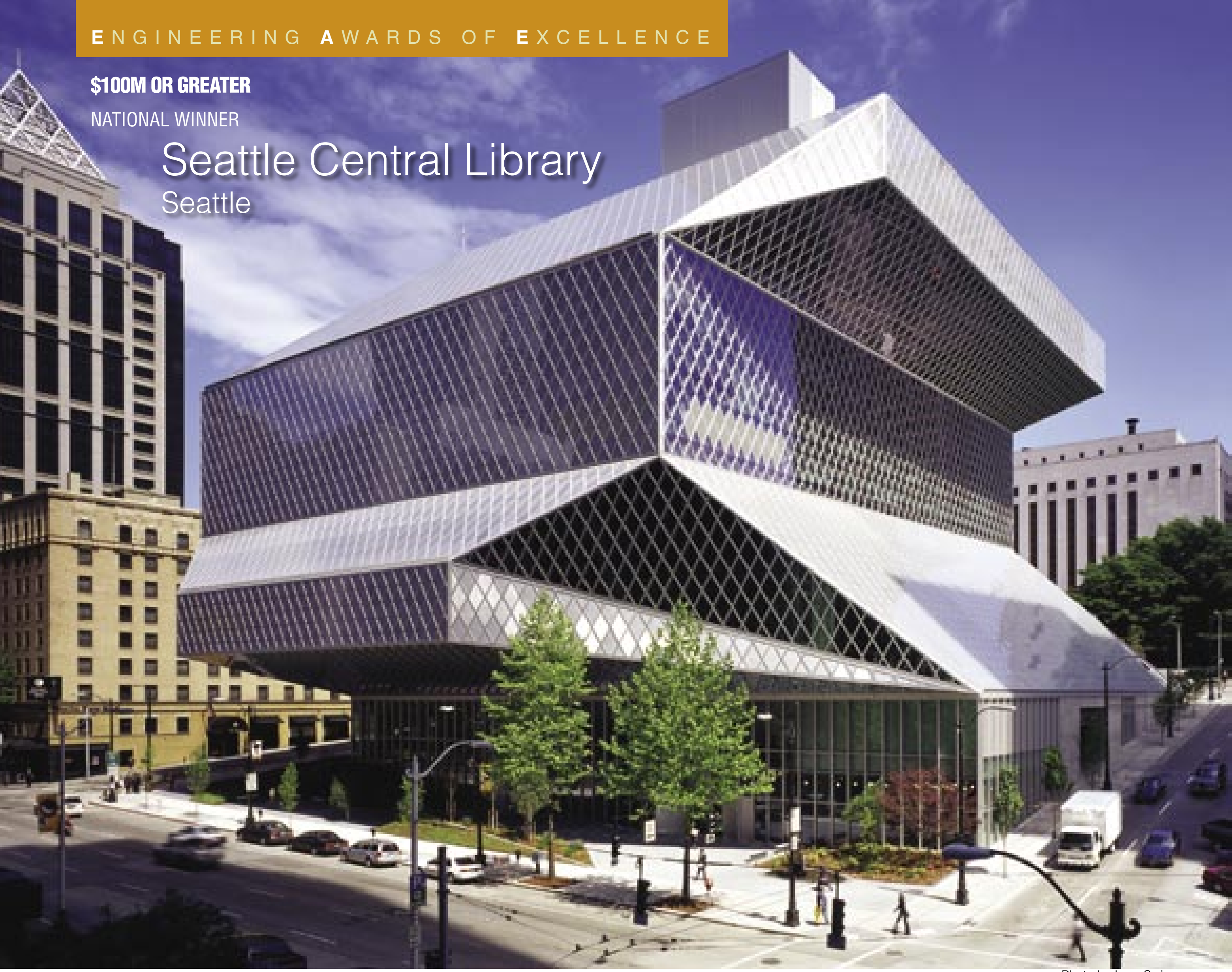


Photo by Lara Swimmer.

JUROR COMMENT

"Very inventive solutions in structural steel to meet complex structural challenges."

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

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

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

Photo courtesy Magnusson Klemencic Associates.

Structural Engineers
Magnusson Klemencic Associates, Seattle

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

Engineering Software
SAP2000

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

LMN Architects, Seattle

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

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

Detailing Software
Xsteel

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

General Contractor
Hoffman Construction Company, Portland, OR

Photo by Michael Dickter, Magnusson Klemencic Associates.

Graphic courtesy Magnusson Klemencic Associates.

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

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

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

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

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

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

Adaptive Reuse of Soldier Field

Chicago

$100M OR GREATER

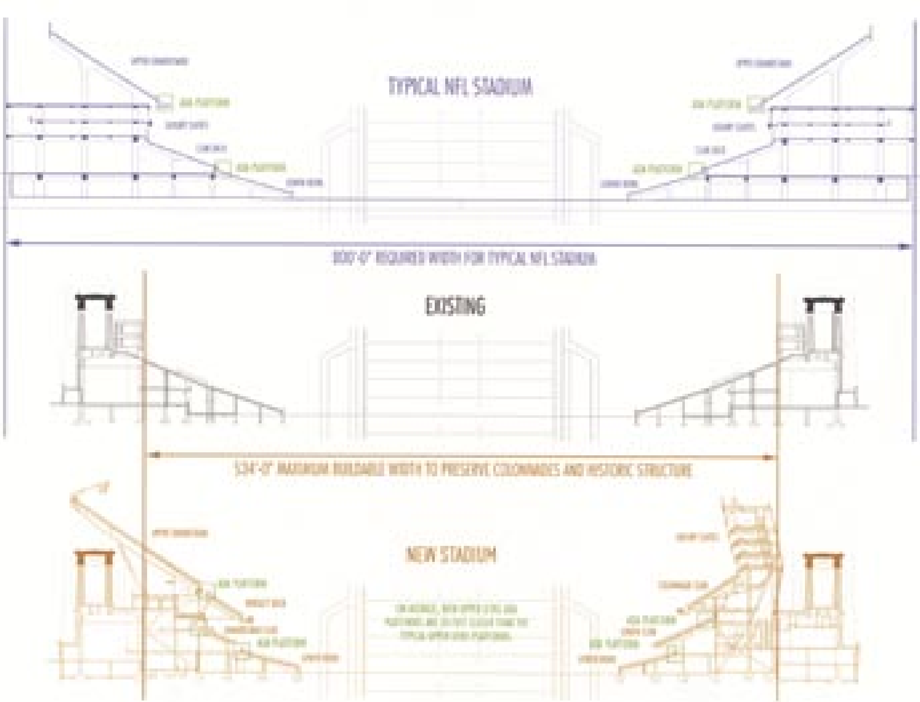
MERIT AWARD

Photo courtesy Thornton-Tomasetti Group.

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

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

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



Graphic courtesy Lohan Caprile Goettsch Architects and Wood + Zapata.

Structural Engineer
Thornton-Tomasetti Group, Chicago

Engineering Software
SAP2000
Ramsteel
AutoCAD

Owner
Chicago Park District—Department of Planning & Development

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

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

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

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

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

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

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

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

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

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

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

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

$100M OR GREATER

MERIT AWARD

St. Luke's Hospital Cardiac Center and Patient Tower

Milwaukee

Photo by David Anderson.

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

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

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

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

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

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

Engineering Software
RAM Structural
Visual Analysis

Owner
St. Luke's Medical Center, Milwaukee

Architect
Kahler Slater Architects, Milwaukee

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

Detailing Software
CDS Asteel

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

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

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

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

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

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

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

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