Field Goals

By Joseph Burns, P.E., S.E, FAIA, and David McLean

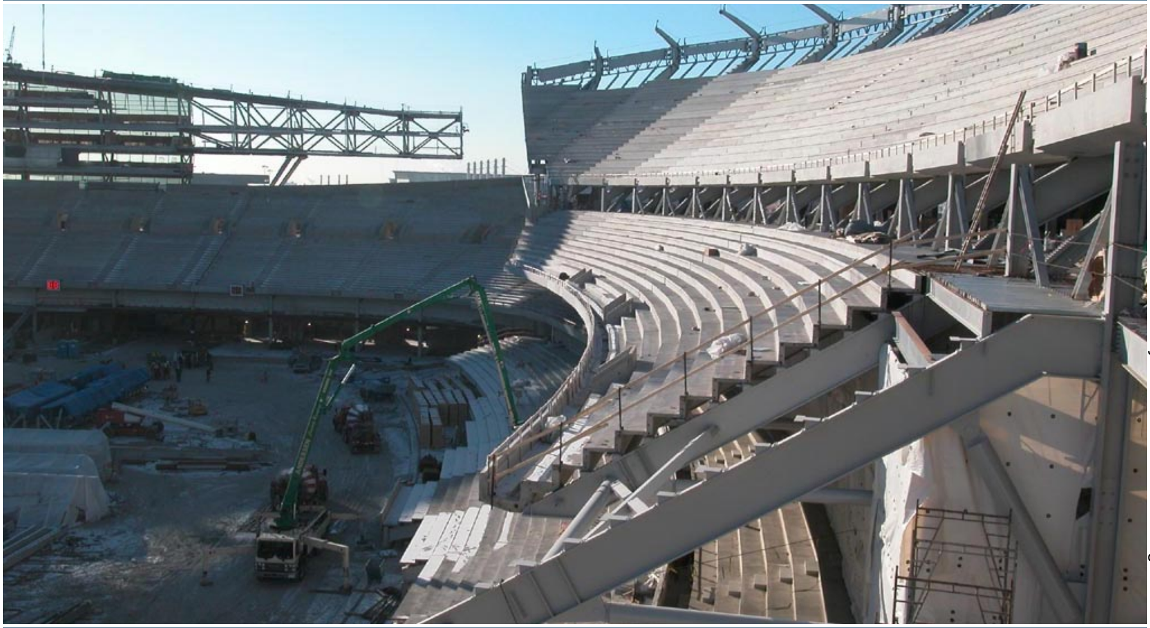


Photo courtesy Thornton-Tomasetti Engineers

Chicago's new Soldier Field tackles complex geometry and construction constraints in the NFL's fastest stadium construction.

Bringing Chicago's historic Soldier Field into the 21st century meant fitting a full-size, modern stadium into a 600'-wide space on a 20-month schedule. Some said the challenge was mathematically impossible, but a project team dedicated to finding innovative solutions used steel to complete the signature stadium within in a tight timeline.

Turning Back the Clock

Home to the Chicago Bears, Soldier Field is the oldest stadium in the National Football League. The stadium, constructed on the Lake Michigan shore during the 1920s in an unsuccessful bid to host the Olympics, features classical colonnades designed by architect Holabird & Roche as a memorial to the fallen soldiers of American wars. Although the Bears played their first game in the stadium in 1926, the team only adopted Soldier Field as their home in the 1970s, after sharing Wrigley Field with the Chicago Cubs for 50 years. Even then, the arrangement was to be a temporary solution while a new stadium was constructed.

During the 1990s, the Bears were still at Soldier Field, but the stadium's infrastructure was crumbling, its facilities were outdated, and it lacked the club seating that was generating substantial revenues for other NFL franchises. The Bears reviewed proposals for stadium projects, including a renovation, a new lakefront stadium, a domed stadium near the McCormick Place convention center, and new stadiums on Chicago's west side, in the city's northwest suburbs and in nearby Gary, IN.

The Bears focused on redeveloping Soldier Field rather than relocating. At first, the challenges seemed insurmountable. With only 600' between the colonnades, the stadium fell more than 100' short of accommodating a conventional football stadium. The solution came from the architects of Boston-based Wood + Zapata. Their solution was an asymmetrical design with all 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 63,000-seat stadium inside the colonnades, while removable ground-level seating would adapt the playing field to regulation size for international soccer competitions. But carrying the inventive design from concept to completion within the demanding schedule would require creative engineering and innovations in steel construction.

Engineering the Solution

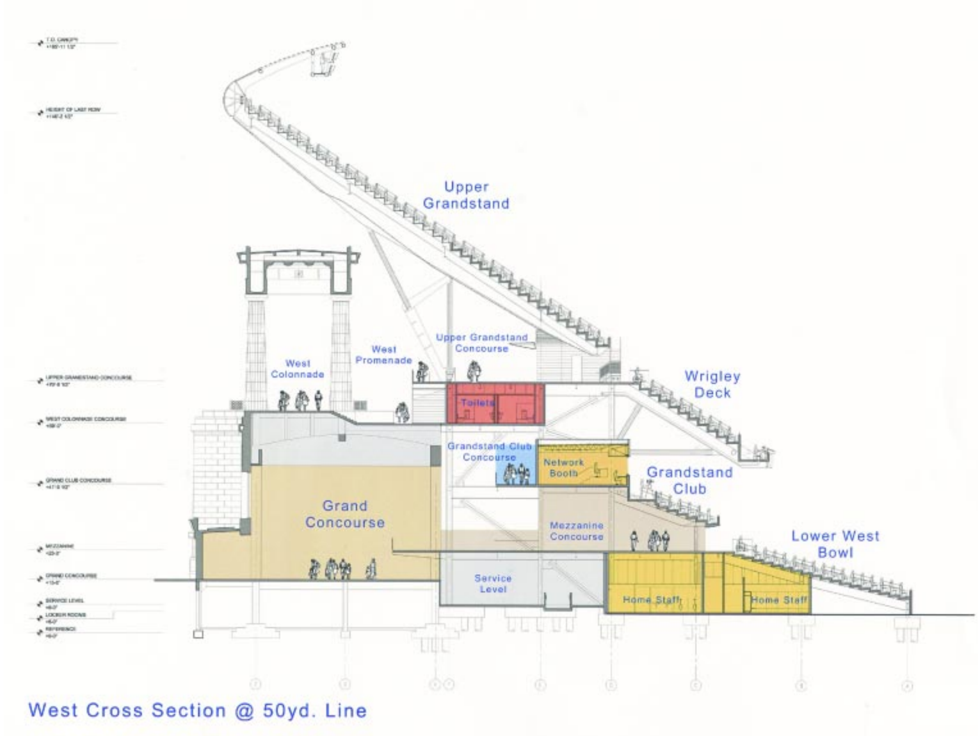
While the old stadium rested on 10,000 timber piles driven through landfill to an average depth of 62', supporting the new stadium required 2,000 H piles driven 90' to 100' down to bedrock. Seating tiers of precast-concrete risers span 40' to their structural steel supports. The rakers supporting the upper grandstand cantilever 60' over the historic colonnades, one of the longest such cantilevers supporting crowds. In another first in stadium design, Thornton-Tomasetti tilted the structure of the suites 14 degrees toward the field, bringing the upper levels of seats closer to the field and providing a better viewing angle. The stadium's two massive video boards, 84' long by 23' high, attach to cantilevered steel trusses extending 90' and 120' in space over the end zones.

Many of these breakthroughs were made possible by the new stadium's 13,000-ton structural steel frame, which provided great design flexibility. However, the steel frame of the upper grandstand cantilever presented Thornton-Tomasetti with another challenge—maintaining fan comfort amidst synchronous crowd movements of zealous fans or avid concertgoers. Because a bare steel-and-concrete structure has very little natural damping to diminish vibrations, a large crowd moving at the structure's natural frequency could create vibrations that would be noticeable to the spectators. Thornton-Tomasetti's 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. Typically, this problem is solved with the addition of more columns, but that option was not possible because of the historic colonnades below the cantilever.

To provide the needed vibration control, the engineers incorporated 21 tuned-mass dampers 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 (similar to a car's shock absorber) connected to the structural frame. When crowd movement causes the structure to vibrate, the TMDs are tuned to vibrate at the same frequency, so the two structures move out of phase, dissipating energy and vibrations. With the TMDs in place, the accelerations near active spectators remain within the limits for spectator comfort.

Rushing Game

Engineering a structure with such a high level of complexity presented a challenge. Completing the design and translating it into a finished product within the required timeframe raised the degree of difficulty considerably. Typically for NFL stadium construction, a 28-month schedule is considered the norm, and no stadium before Soldier Field had been completed in fewer than 24 months. The schedule for redeveloping Soldier



The rakers supporting the west grandstand cantilever 60' over the west colonnade.
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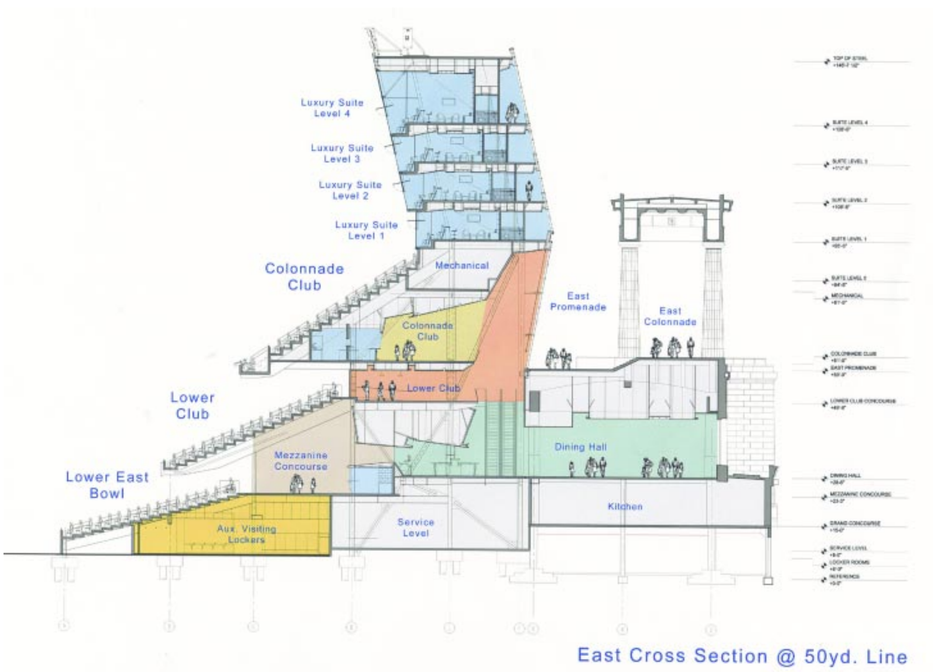

The luxury boxes are all located on the east side of the renovated Soldier Field to maximize the limited buildable width inside the colonnades.
© Lohan Caprile Goettsch Architects and Wood + Zapata

Field during the off-season was ambitious, but when the Bears made the 2001-2002 playoffs, extending their season into January 2002, the window for demolition and redevelopment narrowed to just 20 months.

The schedule had influenced the decision to use a structural steel rather than a cast-in-place concrete frame for the new stadium. Thornton-Tomasetti performed the main structural analysis for the stadium framing with SAP2000 for 3D analysis and Ramsteel for 2D floor framing. With the main structural elements in place, the engineers generated AutoCAD drawings for coordination with the architects. A vast number of shop drawings would be required for steel fabrication, so to accelerate the steel fabrication and erection process, Thornton-Tomasetti, in a joint decision with the project team members, used Xsteel 3D-modeling software by Finland's Tekla Corp. Widely used in Europe, Xsteel produces a full-size, annotated computerized model. Once the model is created, piece drawings for fabrication and general-arrangement drawings can be produced automatically.

Generating 3D models for each of the stadium's four quadrants, Thornton-Tomasetti was able to prepare documentation for the steel beams, beam sizes, member forces and camber required for each beam and column. AISC-member fabricator Hirchfeld Steel Co. Inc. received 3D models from Thornton-Tomasetti and used them to complete the connection detailing, prepare shop drawings and prepare the computer numeric control (CNC) download for the machines used to cut and punch the steel. The drawing-review process consisted of submissions of the 3D model with connections. Because only the connections required examination, the review took only five days instead of the usual 10, saving valuable time on the tightly compressed schedule. The use of Xsteel modeling helped avert costly miscues from design to fabrication and installation. As an added benefit, the 3D geometry of the steel work was available to Permasteelisa Cladding Technologies, facilitating the design and assembly of the stadium's non-rectilinear panelized cladding system. Permasteelisa utilizes 3D modeling program CATIA in the design and production of its cladding systems.

The Whole Nine Yards

For Soldier Field, cladding took on a greater than normal importance. Not only was the unusual configuration challenging to fabricate and install, appearances were critical. Leaving the new stadium with a bare concrete underbelly would have created a jarring effect against the historic colonnades. Stainless-steel cladding on the underside of the bowl clearly delineated the old and new portions of the stadium, each with its own aesthetic. The secondary steelwork necessary to support this cladding was erected with the main superstructure steel.

The aesthetic considerations also tied the stadium into the larger plan for enhancements to 17 acres of surrounding parkland on the Lake Michigan shore. The lakefront improvements, master-planned and overseen by Chicago-based Lohan Caprile Goettsch Architects, include:

- A 40′-high sledding hill, winter garden, terraced park, playground and outdoor exhibit space
- A veteran's memorial granite-clad waterwall
- An additional 2,500 underground parking spaces, a 1,500-space landscaped deck and a 3,100-space surface lot
- Infrastructure work for better traffic control and modern utility connections

The first game at the new Soldier Field was September 29, 2003, and the Bears sold all season tickets and most full-season suites, while the waiting list for single-game suites continues to grow. With steely resolve, the stadium's redevelopment team has beaten both the clock and

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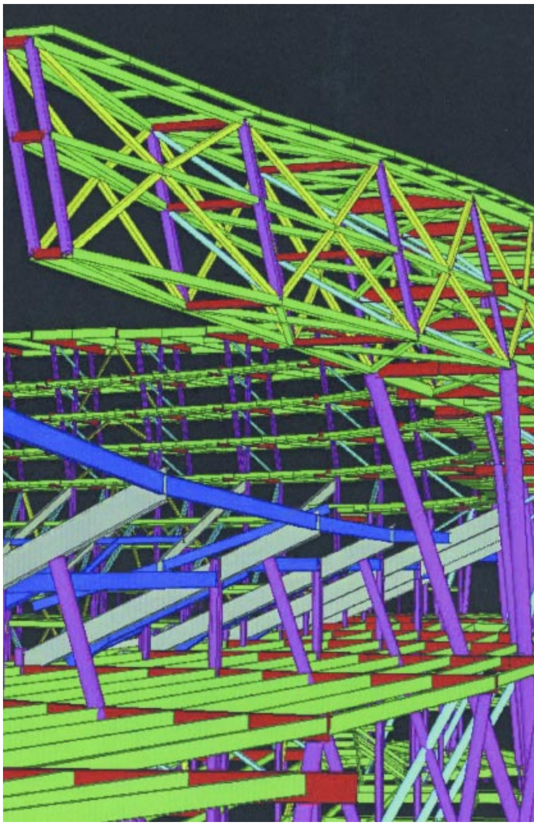

geometric probabilities to score a resounding victory for the future of Soldier Field.

The project was a merit award winner in the $100 million or greater category of the 2004 IDEAS awards. ★

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Owner
Chicago Park District

Developer
Chicago Bears Football Club, LLC

Developer's Representative
Hoffman Management Partners LLC, Chicago

Construction Manager
TBMK, a joint venture of Turner Construction Co. (Chicago), Barton Malow Co. (Southfield, MI) and Kenny Construction (Wheeling, IL)

Structural Engineer
Thornton-Tomasetti Engineers (Chicago)

Architect
LW+Z, a joint venture of Lohan Caprile Goettsch Architects (Chicago) and Wood + Zapata Architects (Boston)

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

Engineering Software
SAP 2000, RAM Structural System

Detailing Software
Tekla Xsteel

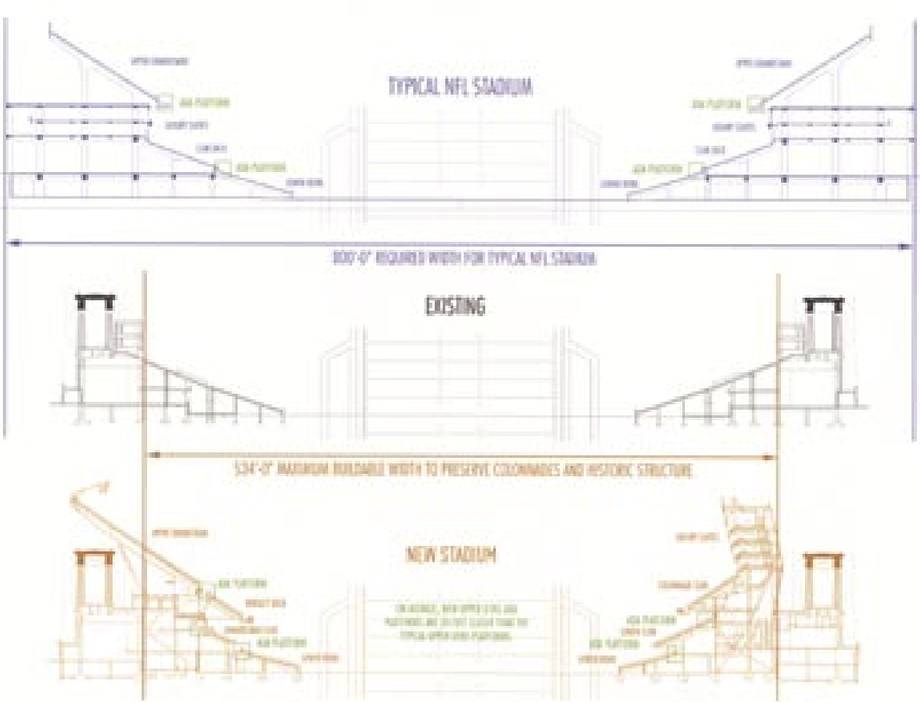
Adaptive Reuse of Soldier Field

Chicago

$100M OR GREATER

MERIT AWARD


Photo courtesy Thornton-Tomasetti Group.



Graphic courtesy Lohan Caprile Goettsch Architects and Wood + Zapata.

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

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

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

Structural Engineer
Thornton-Tomasetti Group, Chicago

Engineering Software
SAP2000
Ramsteel
AutoCAD

Owner
Chicago Park District—Department of Planning & Development

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

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

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

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

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. ★