It's Up... IT'S GOOD!

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Levi's Stadium, home of the San Francisco 49ers and Super Bowl 50, sets NFL records for seismic design and timely completion.

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AS OF LAST MONTH, Levi's Stadium has its first Super Bowl under its belt.

And like the two teams in that game (the Denver Broncos, who won, and the Carolina Panthers), the stadium's design and construction team had to overcome some pretty big obstacles: a project location that tops all NFL stadiums in terms of seismicity and a construction schedule that was accelerated by one year with project design already underway.

Hybrid Project Delivery

Located in Santa Clara, the new home of the San Francisco 49ers has a seating capacity of 68,500 but is expandable to 75,000 (and in fact has already exceeded the latter number by nearly 2,000 during a professional wrestling event last year). To best facilitate the delivery of this large and complex structure within the aggressive construction schedule, the 49ers and the stadium's owner, the Santa

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- The stadium uses 17,000 tons of structural steel.

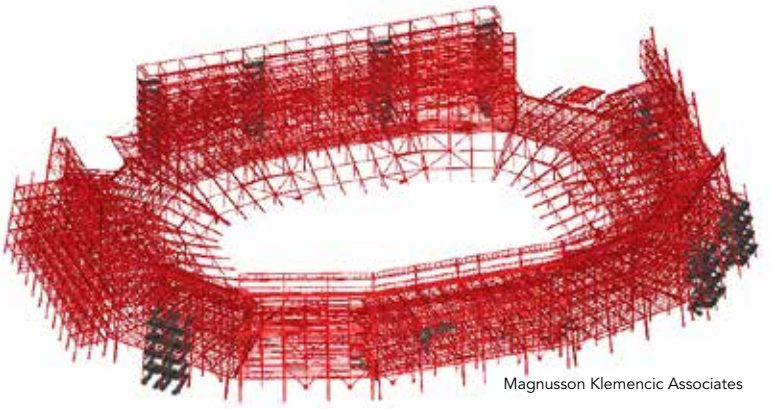
Clara Stadium Authority, opted for a new hybrid project delivery model dubbed "integrated bridging design-build" (IBDB). Levi's is the first NFL stadium to use IBDB delivery, a highly collaborative and enhanced version of traditional bridging design-build (BDB). This approach was chosen in order to limit risk and eliminate potential owner, architect and contractor disputes and cost overruns common with stadium projects.

In March 2006, the 49ers and the Stadium Authority selected Turner Construction for preconstruction services as well as architectural firm HNTB and structural engineer Magnusson Klemencic Associates (MKA) for the initial design phases. For five years, the design and preconstruction team endured a series of project starts and stops, including a site move from San Francisco's Candlestick Point to Santa Clara in Silicon Valley.

As the architectural and structural design efforts advanced, an ongoing process of value analysis and cost modelling allowed development of a reliable initial guaranteed maximum price (IGMP) for the project to be developed based on a preliminary design. With the IGMP established and preliminary design accepted, the Stadium Authority retained Turner/Devcon, Joint Venture, (TDJV) as the design/build contractor. Under the IBDB process, the design team worked first for the owner/developer through the IGMP phase, then became designers-of-record under direct contract with TDJV to complete the design of the project. This was critical in terms of holding the design and construction team to the established guaranteed price and satisfying the requirements of the preliminary design, while also meeting an aggressive procurement and construction schedule.

A financing opportunity presented itself in the fall of 2011 but included a one-year project acceleration, and the project team went into overdrive to finish in time for the 2014 NFL season. Once all IBDB team members—both as firms and individuals—committed to the extreme acceleration, the team collectively phased, streamlined and "stacked" the design schedule, shortening it by seven months.

MKA agreed to phased delivery of the structural packages, with structural steel on the critical path, requiring that construction documents be completed in the middle of the design development phase of the project. To facilitate local permitting, MKA also proposed a combined peer review/plan check process to expedite a rigorous structural design review and permitting process. By splitting the stadium's structure into eight plan-check packages, MKA continued to engineer packages while others



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In addition to football, the 1.9-million-sq.-ft facility is designed for soccer, concerts and other high-attendance events.

Turner Construction

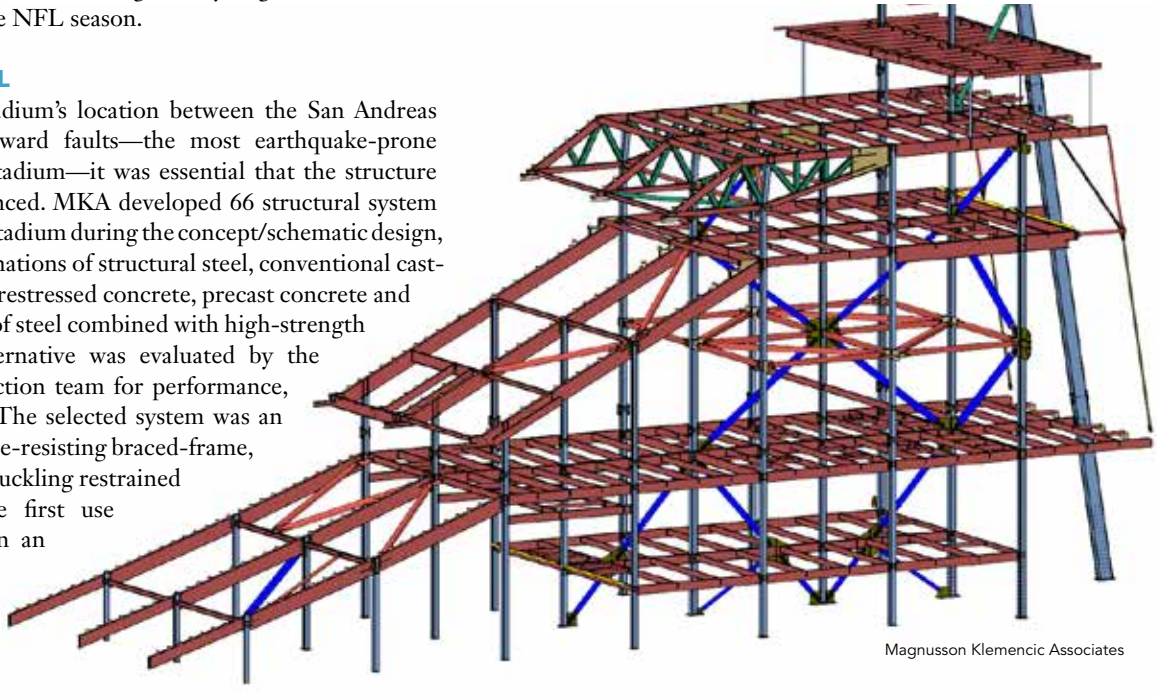
▲ Steel framing for the seating.

▼ A sample section of the stadium's framing system; BRBs are shown in blue.

were in review, saving more than two months in terms of project delivery. In addition, the stadium was designed as four separate structures to facilitate simultaneous four-quadrant construction versus more traditional (and lengthier) "racetrack" sequencing. Ultimately, construction of the stadium took just 28 months, starting in April 2012 and finishing in early August 2014, in time for the kickoff of the NFL season.

A First for the NFL

Given Levi's Stadium's location between the San Andreas and Calaveras/Hayward faults—the most earthquake-prone of any U.S. NFL stadium—it was essential that the structure be seismically advanced. MKA developed 66 structural system alternatives for the stadium during the concept/schematic design, including all combinations of structural steel, conventional cast-in-place concrete, prestressed concrete, precast concrete and composite systems of steel combined with high-strength concrete. Each alternative was evaluated by the design and construction team for performance, schedule and cost. The selected system was an all-steel, lateral-force-resisting braced-frame, incorporating 529 buckling restrained braces (BRBs)—the first use of such a system in an NFL stadium. BRBs are high-performance



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▲ The BRBs range in capacity from 100 kips to 1,800 kips and are arranged in U-shaped "brace cores" around concessions and other areas.

steel brace elements designed to specifically absorb forces generated during an earthquake—and the buckling restrained braced frames (BRBFs) used here are more efficient and provide higher capacity and greater architectural flexibility compared to conventional steel braced frames. The lateral system configuration developed by MKA required only half the number of braces compared to a traditional braced frame system while effectively addressing the area's intense seismic demands.

Erecting the BRBFs was no more difficult than conventional braced frames, with erection of the steel frame starting in August of 2012 and topping out less than five months later. The incorporation of BRBs produced a structural system six times lighter than a concrete shear wall design and one that required significantly less steel than a moment-resisting frame. The BRB system also improved seismic performance, reduced structural costs by 13% and reduced foundation costs by 20%.

Although Levi's Stadium sits on one of the smallest stadium sites in the NFL, the highly compact framework created by the steel/BRB structure delivered the wide-open spaces envisioned. MKA also optimized the space by cantilevering and "hanging" 40 ft of concourse off the suite tower structure, providing column-free plaza space below. In addition, the stadium's perimeter box columns are sloped, and the bay spacing increased to 64 ft with an inverted king-post rod truss to achieve an open and visually interesting exterior. (The box columns, 24 in. wide by 36 in. deep, are approximately 200 ft in length when spliced together.)

The BRBs range in capacity from 100 kips to 1,800 kips and are arranged in U-shaped "brace cores" around concessions, stairs and restrooms on each level of the five-story stadium and eight-story suite tower. The system creates generous interior passageways with an open main concourse measuring more than 60 ft wide by 45 ft high. The concourses are concrete slab on metal deck, and the tri-level seating bowl comprises precast concrete tread and riser units. In-plane steel bracing below the seating bowl transfers lateral forces to the braced frames and provided stability to the structure during erection. The superstructure is supported by 3,000 drilled concrete pilings up to 60 ft deep that anchor the stadium through soft soils into solid ground.

Box Score

Square Footage	1.9 million sq. ft
Project Cost	$930 million
Under Budget	$80 million
Structural Concepts Evaluated	66
Structural Steel	17,000 tons
BRBs	529
BRB Capacity	Up to 1,800 kips
Construction Time	28 months

▲ Levi's Stadium incorporates 529 BRBs, the first use of such a system in an NFL stadium.

Integrated Bridge

The *bridging design-build* (BDB) project delivery method is a fairly common variation of design-build (DB). An A/E team is contracted by an owner to design a project to a "design intent" level of documentation, then DB teams compete for the project using that documentation. Upon contract award, the DB team completes the design (under the obligation to satisfy the design intent) and constructs the project. The A/E team is under contract with the contractor in a DB arrangement.

Under the *integrated bridging design-build* (IBDB) model, the A/E team is initially contracted by an owner to develop the "design intent" for the project. This A/E team is then assigned to the owner's selected contractor, who will then be responsible for designing and constructing the project under a DB contract. This arrangement effectively allows for better project design continuity because the original design team completes the design from which they originally established the intent. In this scenario, the initial A/E team completes the design of the project under contract with the contractor in a DB arrangement.

Express Delivery

In addition to football, the 1.9-million-sq.-ft facility is designed for soccer, concerts and other high-attendance events. The eight-level luxury suite and press tower on the stadium's west side is topped by a living green roof terrace and solar panels, contributing to the project's LEED Gold rating (another NFL first).The all-steel superstructure uses 17,000 tons of structural steel plus approximately 6,000 tons for stairs and miscellaneous use. The stadium's delivery—over one month ahead of even the accelerated schedule, another NFL record—was celebrated with an inaugural soccer game on August 2, 2014. At $930 million, the final construction cost was more than $80 million under budget, which has accelerated the payoff of public debt on the stadium—another big win. ■

Owner
Santa Clara Stadium Authority

Tenant
San Francisco 49ers NFL Club

Design-Builder
Turner Construction/Devcon Construction Joint Venture

Architect
HNTB

Structural Engineer
Magnusson Klemencic Associates

Steel Team

Fabricators
SME | Hirschfeld JV:
SME Steel Contractors, Inc.
Hirschfeld Industries

Erector
SME Steel Contractors, Inc.

Detailers
Prodraft, Inc.
Steel Systems Engineering, Inc.
SMECAD (a division of SME Steel Contractors)

BRB Supplier
CoreBrace, LLC

Miscellaneous Metals
Southwest Steel