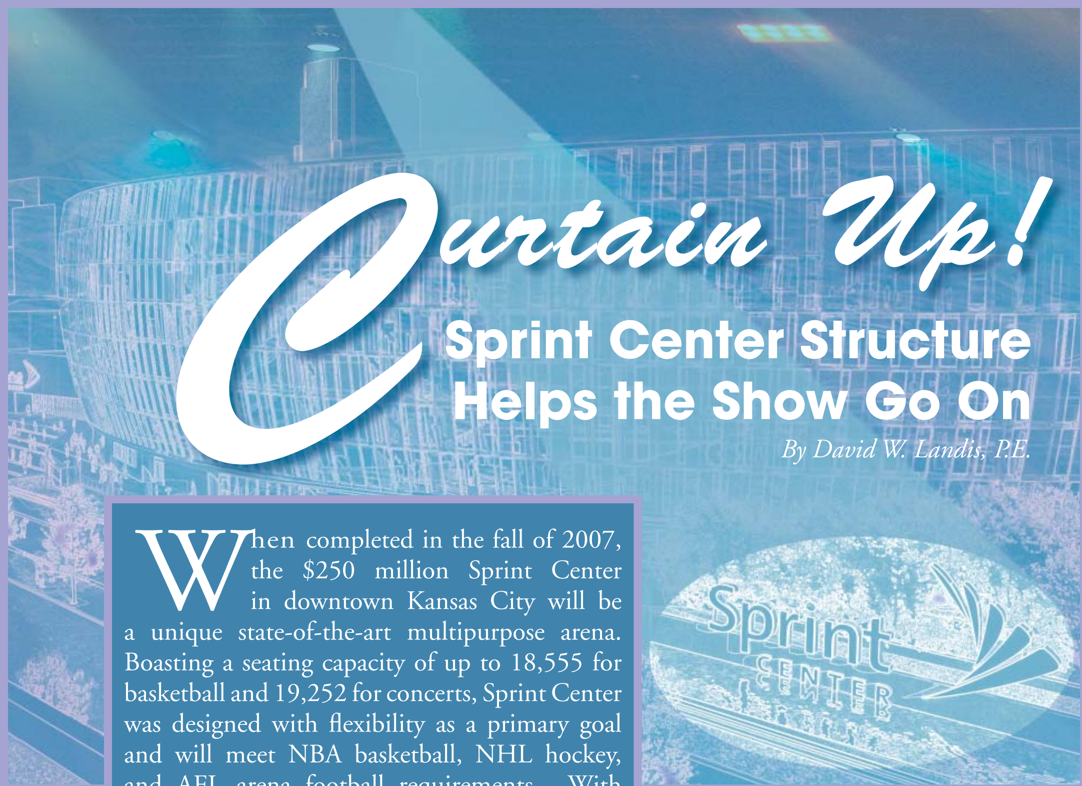


Curtain Up!

Sprint Center Structure Helps the Show Go On

By David W. Landis, P.E.

When completed in the fall of 2007, the $250 million Sprint Center in downtown Kansas City will be a unique state-of-the-art multipurpose arena. Boasting a seating capacity of up to 18,555 for basketball and 19,252 for concerts, Sprint Center was designed with flexibility as a primary goal and will meet NBA basketball, NHL hockey, and AFL arena football requirements. With retractable and variable rise seating to optimize sight lines, the arena will be reconfigured quickly to accommodate various sporting events, concerts, or other performances.

The design team is an unprecedented alliance of the nation's leading sports facility designers. Located in Kansas City, and having collectively designed 24 of the last 28 NBA/NHL arenas around the country, HOK Sport, Ellerbe Becket, and 360 Architecture joined forces to form the Downtown Arena Design Team. The Kansas City office of Walter P. Moore is lead structural engineer. Walter P. Moore has been instrumental in the design of nearly 40 arenas around the country. The developer, Anschutz Entertainment Group and Icon Venue Group, develop and operate arenas around the world. Collectively, the project team provided a level of leadership, experience and passion like no other.

The structural systems will be a key element in the success of this high profile building. In particular, the roof structure will give Sprint Center extraordinary flexibility to host a wide variety of shows and stage configurations. To meet an aggressive design and construction schedule, structural bid and construction documents were issued when the remainder of the design team was just completing Design Development. Drilled pier foundation installation began in October 2005, while the structural frame was out to bid and the balance of the design still incomplete.

Figure 1: Exterior rendering – southwest elevation Courtesy Downtown Arena Design Team

Structural System Selection

Following a series of design charrettes with the project team, several building configurations and structural systems were explored. Qualitative and quantitative analyses were conducted to evaluate each system for functional, cost, and schedule considerations. Final selection of the structural systems was a team effort, with significant input from the construction manager, M.A. Mortenson.

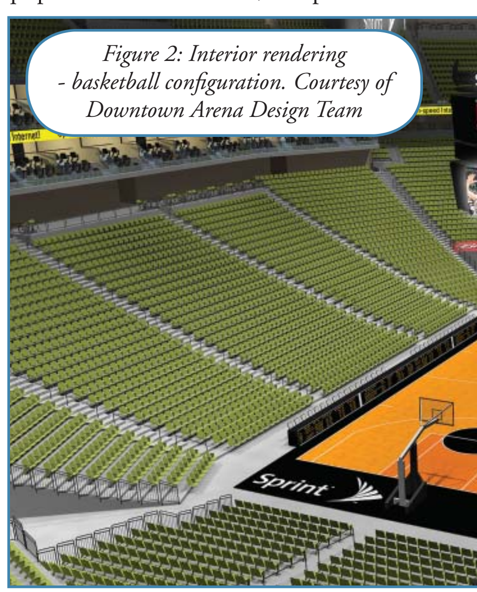
A cast-in-place concrete pan-formed beam and slab system was selected for the club/office level, main concourse level, and two suite levels. Floor-to-floor heights at these levels allowed economical forming. Floor framing changed to structural steel above the suites, to eliminate the cost of shoring and formwork at these taller levels. The upper concourse and press levels are framed with composite metal deck slabs and composite steel beams and girders. Lateral loads are resisted by a combination of basement walls, concrete ordinary moment frames, and steel concentrically braced frames. *Figure 3* illustrates the primary structural systems.

The lower seating bowl blends precast and cast-in-place concrete columns and raker beams supporting precast stadia units with spans up to 41 feet. Precast stadia units at both suite levels are supported on cantilevered cast-in-place concrete raker beams. The upper bowl precast stadia units are supported on W40 steel girders. In addition to strength requirements, the stadia units and supporting raker beams were sized to limit accelerations caused by rhythmic excitation from fan participation. AISC *Design Guide 11* and PCI *Design Handbook*, 6th Edition, formed the basis of the vibration analysis.

Roof System Selection

The roof clear spans 334 feet across the short direction of the seating bowl. In addition to code live and snow loads, the roof was designed to support a whopping 425,000 pounds of show rigging for concerts, plus an 80,000-pound scoreboard, four 8,000-pound speaker clusters, and nearly half a mile of catwalk loaded with sports lighting, spotlights, and electrical and sound equipment. Of the 425,000-pound show rigging capacity, approximately 225,000 pounds is available for an end stage configuration, 175,000 pounds for a center stage configuration, and the remainder to accommodate other configurations. Other equipment supported from the roof includes hoist platforms and hoists for the scoreboard and each of the speaker clusters, motorized curtain systems, lapendary panels for acoustical control, and roof signage. In addition to applied loads, the effect of temperature

Figure 2: Interior rendering - basketball configuration. Courtesy of Downtown Arena Design Team



and volumetric changes on the long-span roof system and supporting structure were considered, including stresses resulting from system restraint and expected movements.

For long-span roof systems, the self weight of the structure is usually the most significant contributor to total design load. Even truss connections must be carefully considered, since they can add from 5% to as much as 35% to the truss weight self weight, depending upon truss configuration and connection type. Even with the considerable show loading, the Sprint Center long-span roof steel weighs about 25 psf, including primary and secondary structural elements, rigging grid, catwalks, hoist platforms, connections, equipment supports, bracing and bridging, deck support plate, etc.

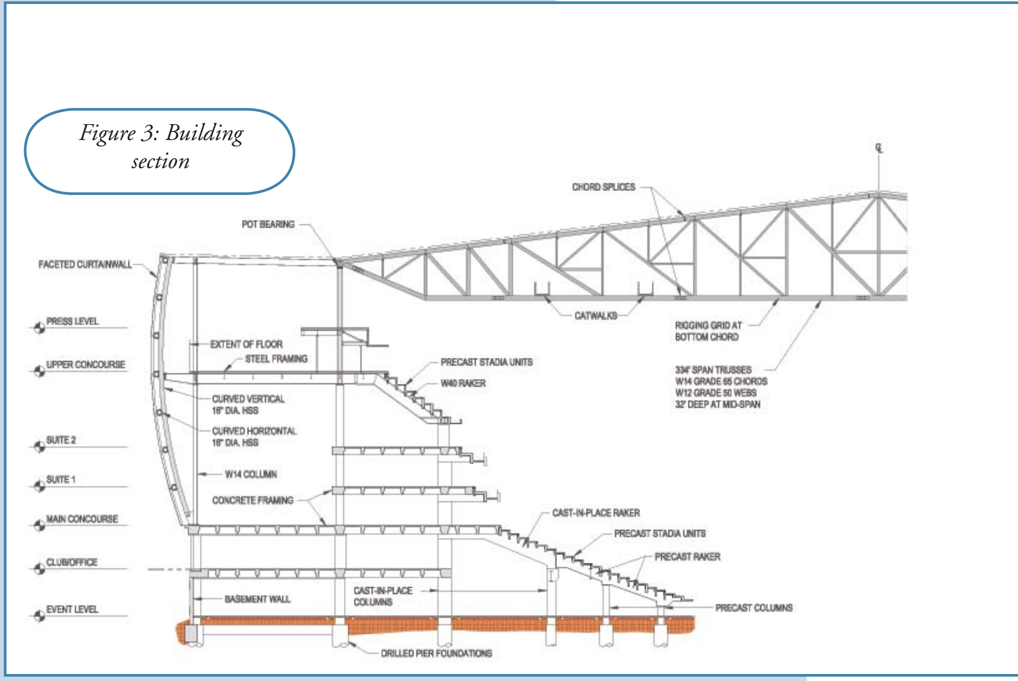
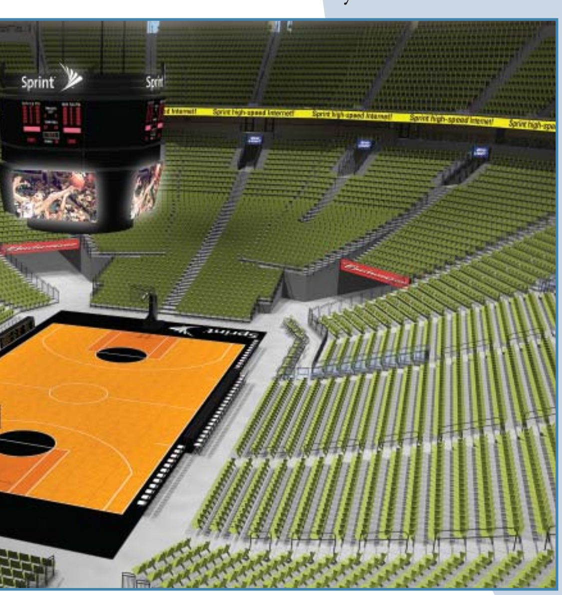


Figure 3: Building section

Walter P. Moore evaluated a number of different long-span systems before arriving at the final roof configuration. One-way systems considered included planar trusses, box trusses, and tied arches, all spanning approximately 334 feet across the short direction. Two-way systems considered included two-way planar trusses, two-way box trusses, two-way tied arches, and an elliptical dome.

In comparing the various one-way and two-way roof systems, total steel tonnage, fabrication and erection complexity, constructibility, erection sequence, schedule, and impact on the supporting structure below were considered. One-way systems are generally less complicated to fabricate and erect than two-way systems, but two-way systems can potentially require less steel, depending upon span lengths in each direction and system configuration. Connections for the two-way systems are generally more complicated, and the erection sequence has a larger impact. Therefore, a lighter two-way system would not necessarily cost less than a slightly heavier one-way system. (The old adage "Least weight does not necessarily mean least cost," holds true for long-span roof systems as well.) Man-hours per ton, or cost per ton, had to be considered along with pounds per square foot, or total tons, for the different systems.

Different fabricators and erectors will often disagree on the "best" system, since they often have their own preferred practices. However, the team did not have the luxury of having the fabricator/erector team involved during design. To make sure that each of the above factors was appropriately considered, Walter P. Moore worked closely with the construction manager. After weighing cost, constructibility and schedule implications for the various long-span systems considered, one-way planar trusses were selected.



Next, the truss member steel grade had to be selected. ASTM A992 (Grade 50) rolled shapes are readily available domestically, but only for member sizes up to around 400 plf. Heavier rolled shapes, and shapes rolled with higher grades of steel such as ASTM A913 Grade 65, are available only from overseas producers. With a 30% increase in yield strength over Grade 50, using Grade 65 steel would allow us to reduce steel tonnage significantly. However, since the Grade 65 shapes would have to be procured overseas, schedule implications had to be considered. For Sprint Center, the schedule impact was expected to be minimal, since significant construction must occur prior to erecting the roof trusses. After investigating the potential savings and schedule implications with the construction manager, we selected Grade 65 steel for truss members W14x90 and larger and Grade 50 steel for truss members less than 90 plf. This resulted in a savings of approximately 130 tons of truss steel.

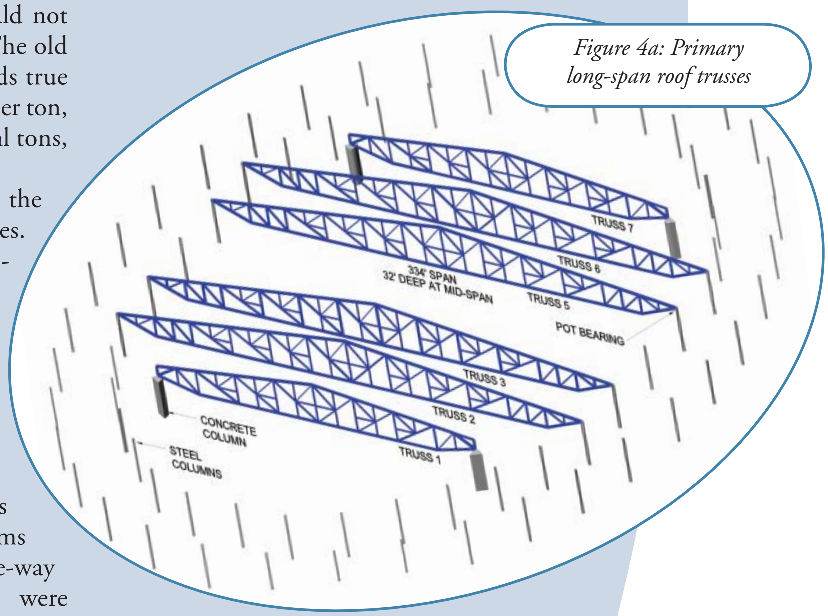


Figure 4a: Primary long-span roof trusses

Figures 3 and 4a illustrate the geometry of the Sprint Center long-span primary trusses, which span 334 feet over the seating bowl. The deepest trusses are 32 feet deep at mid-span and taper down towards the ends. Truss top chords slope approximately 1.5 in 12 to form the roof slope. All truss bottom chords are horizontal and at the same elevation to support the rigging grid and catwalks, which are slightly over 100 feet above the playing floor.

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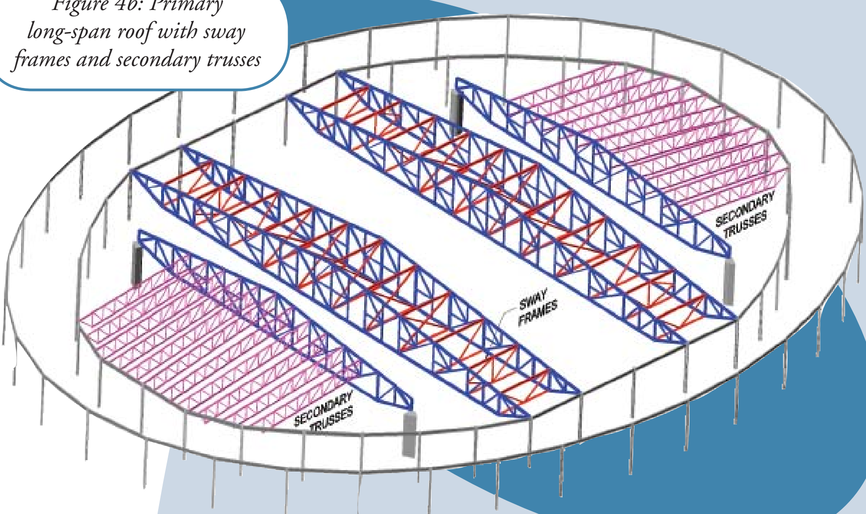


Figure 4b: Primary long-span roof with sway frames and secondary trusses

As indicated in the figures, truss bottom chords slope up at the ends to bear on pot bearings on the supporting columns. The pot bearings support heavy vertical loads while at the same time allowing the trusses to rotate. Sloping the truss bottom chords up to the supports accomplished two objectives: First, it allowed the trusses to be at a lower elevation, thus reducing the roof profile and the overall height of the building, which was one of the architect's design goals. Second, the bearing points are located near the truss neutral axis, which significantly reduces the truss end movements due to flexural action. This reduces lateral forces and movements imposed on the supporting columns.

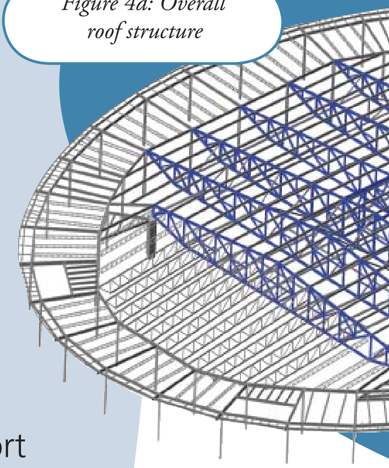
Truss stability is accomplished using a torsional bracing concept, provided by vertical "sway frames" between trusses (*Figure 4b*), which provide stability in the final condition as well as during erection. W21 roof purlins span between truss top chords and support 3-inch roof deck. W14's span between truss bottom chords to form the rigging grid and complete the truss bracing system. Secondary trusses consisting of WT chords and double-angle webs span up to 104 feet at each end of the arena, from columns at the back of the seating bowl to the outer primary roof trusses. Roof lateral loads are collected in the roof deck and delivered to steel braced frames and concrete columns.

Truss chords are Grade 65 W14's oriented web-horizontal and truss web members are Grade 50 W12's. Gusset plates connect the flanges of the W14 chords to the flanges of the W12 webs. Gussets are shop-welded to the tips of the W14 chord flanges and field-bolted to the W12 flanges with X-type bearing bolts. To simplify connections, compression chords are spliced away from the panel points with end-plate bearing splices. Tension chords are also spliced away from the panel points, but with conventional splice plates each side of the chord flanges and web. *Figure 5* illustrates a typical truss panel point top chord connection.

All truss connections were designed and scheduled in the construction documents. Bolts were standardized at 1 ⅛-inch diameter A490 bolts for large connection forces and ⅞-inch diameter A325 bolts for smaller connection forces. The 1 ⅛-inch A490 bolts were selected because they are the largest bolts that can readily be fully tightened using standard equipment and practices. Standard holes with X-type bearing bolts were used for truss member connections. This minimized the number of bolts and kept the truss connections compact. Preassembly of trusses in the shop was specified to verify fit-up prior to shipping to the site. To provide reasonable erection tolerances, slotted or oversized holes with slip-critical bolts were specified for members framing between trusses.

For any long-span roof structure, due consideration must be given to the erection sequence. For Sprint Center, an erection sequence was developed during design in conjunction with the construction manager. The erection sequence took into account erection tower locations, truss stability during erection, and impact on other trades, such as erection of the precast stadia units. A step by step erection sequence was shown on the structural drawings. The erector may use the erection sequence outlined in the drawings, or may elect to use a different sequence. In either case, the erector is required to submit a detailed erection plan for review and approval. The erection plan must be accepted by both the design team and the construction manager.

Figure 4d: Overall roof structure



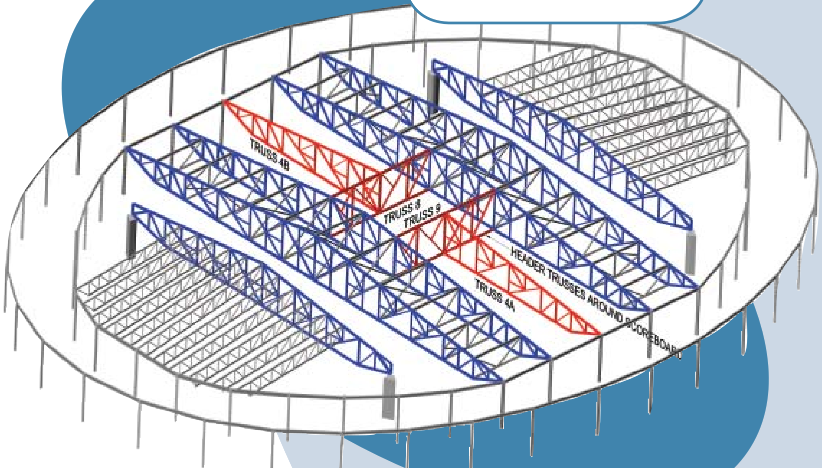


Figure 4c: Header trusses and infill trusses around scoreboard well

Curved Cladding Support

The project's most notable aesthetic design feature is its distinctive cladding system. Curved both vertically and horizontally, the faceted cladding system is somewhat reminiscent of a crystal bowl. The faceted glazing, as well as varied frit patterns applied to the glazing, will make the building appearance change as sun angles and light conditions change throughout the day.

Numerous schemes for structural support of the cladding were investigated with the architects and construction manager. To respond to the architect's desire for an elegant and non-distracting support structure, a system of curved vertical and horizontal pipe was selected. Curved horizontal 16-inch diameter HSS span up to 50 feet to curved vertical 16-inch diameter HSS spanning up to 48 feet. Horizontal HSS are moment connected with end plates to reduce deflections. End plate connections with oversized holes allowed for reasonable erection tolerances while providing economical moment connections. The moment connections permitted the use of smaller diameter HSS for strength and deflection

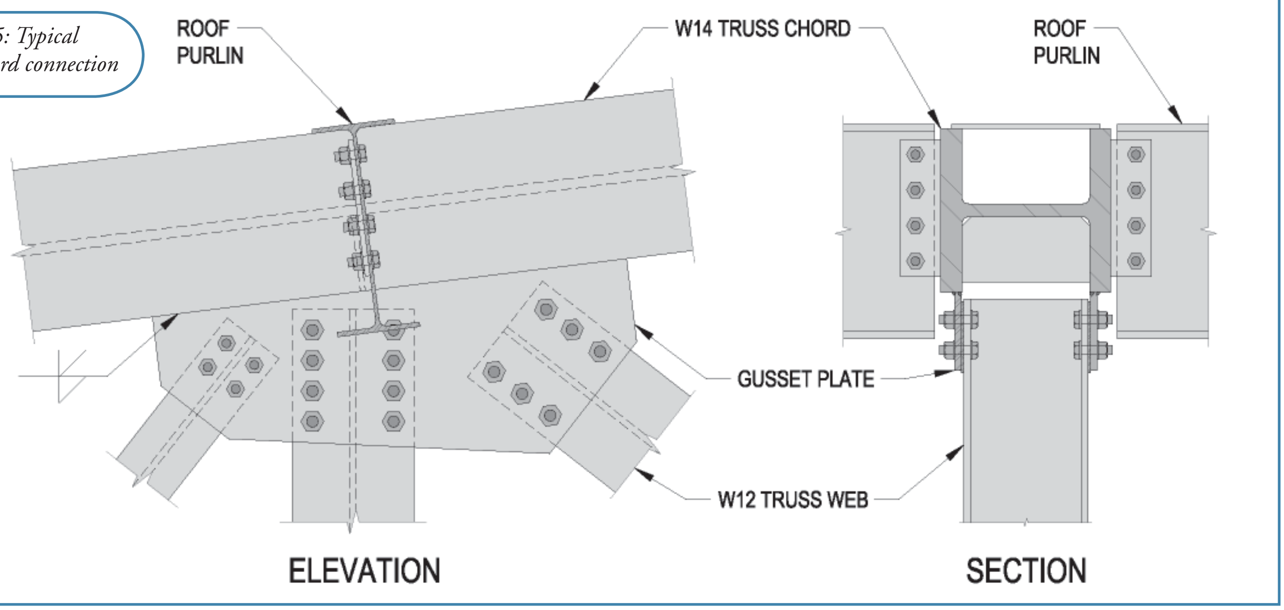
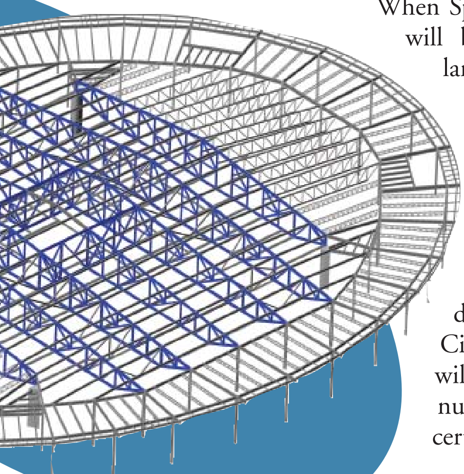


Figure 5: Typical truss top chord connection

requirements. Steel tolerances for the curved frame were reduced from those in the AISC Code of Standard Practice to facilitate connection of cladding system. Building and support frame movements to be accommodated by the cladding system were outlined on the drawings for the curtainwall manufacturer.

When Sprint Center opens fall 2007, the arena will be Kansas City's newest downtown landmark, situated adjacent to a new entertainment district. Given the unique building configuration, Sprint Center will present its "best side" to all parts of the surrounding city. Inside, the spacious concourses will provide spectacular views in all directions of downtown Kansas City, and the world-class arena will comfortably accommodate numerous sporting events, concerts and shows.▪



David W. Landis, P.E., is a Principal in the Kansas City office of Walter P. Moore and has been involved in the structural design of over 20 sports facilities. Walter P. Moore is a multidisciplinary consulting engineering firm based in Houston, TX.
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Project Team – Principal Players

Owner: City of Kansas City, Missouri

Owner's Program Managers:
Burns & McDonnell (Kansas City, MO)
HNTB (Kansas City, MO)
PC Sports (Bokeelia, FL)
Taliaferro & Browne (Kansas City, MO)

Developer/Arena Manager:
Anschutz Entertainment Group (Los Angeles, CA)
Icon Venue Group (Greenwood Village, CO)
(representing AEG)

Construction Manager:
M.A. Mortenson Company (Minneapolis, MN)

Architect:
Downtown Arena Design Team:
HOK Sport (Kansas City, MO)
Ellerbe Becket (Kansas City, MO)
360 Architecture (Kansas City, MO)
Rafael Architects (Kansas City, MO)

Associate Architects:
Ronald A. Posey & Associates (Kansas City, MO)
Group One Architects (Kansas City, MO)

Structural Engineer:
Walter P. Moore (Kansas City, MO)
(Engineer of Record)

Associate Structural Engineers:
DuBois Consultants (Kansas City, MO)
KH Engineering Group (Kansas City, MO)

All renderings courtesy of Walter P. Moore, unless otherwise specified.