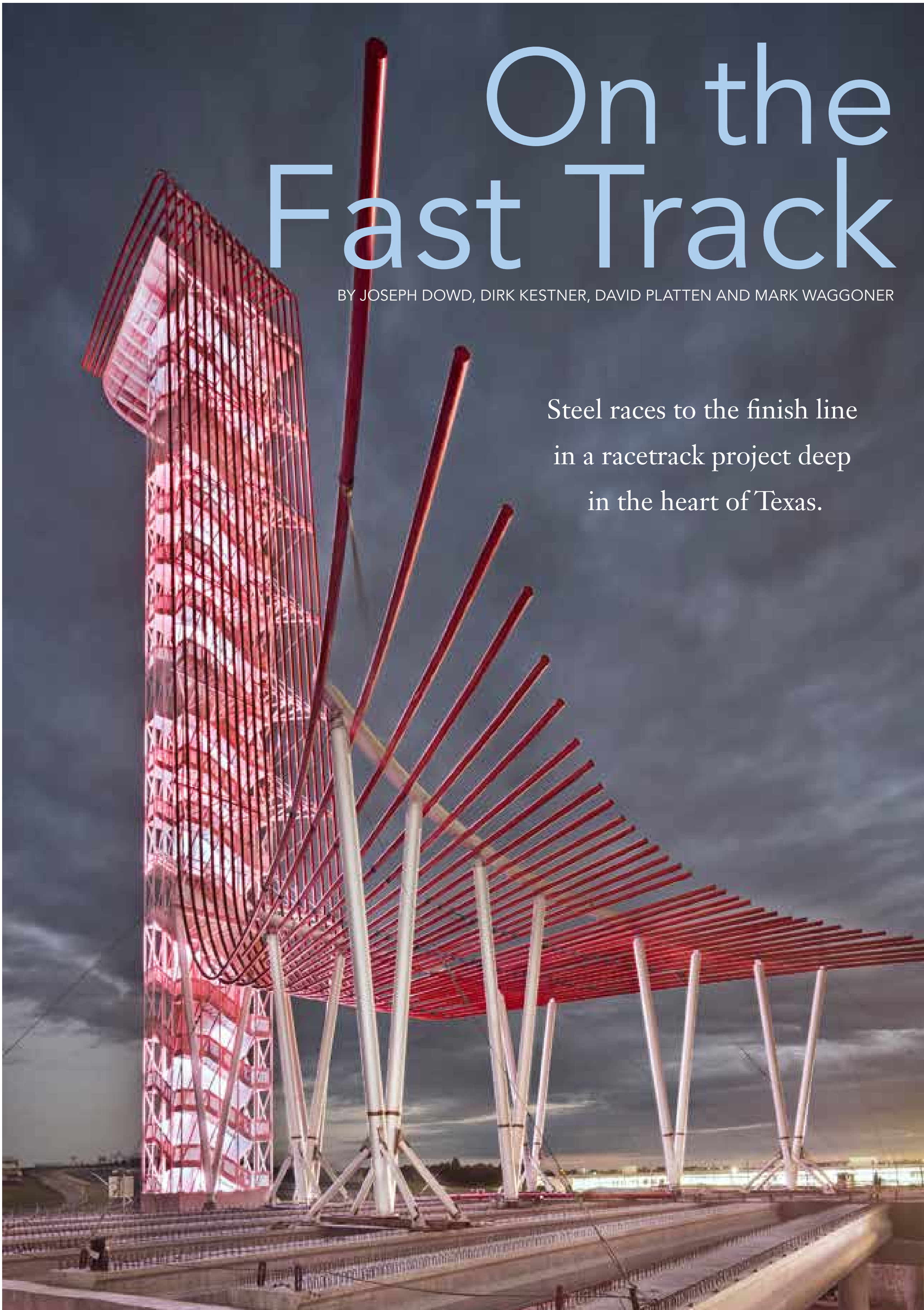
On the Fast Track

BY JOSEPH DOWD, DIRK KESTNER, DAVID PLATTEN AND MARK WAGGONER

Steel races to the finish line in a racetrack project deep in the heart of Texas.



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IN MAY OF 2010, Formula 1 (F1) announced that the United States Grand Prix would be held in Austin, Texas from 2012 to 2021.

The news was exciting, but the sprint was now on to complete the Circuit of the Americas (COTA) racetrack, the first purpose-built F1 track in the U.S., in time for its first race on November 18, 2012.

A team of investors embarked on the journey by first hiring world-renowned German track designer Tilke Engineers and Architects. Tilke would provide the 330-acre facility master plan and track design on an 1,100-acre site located southeast of downtown Austin, just minutes from the Austin-Bergstrom International Airport. Numerous U.S. architectural, engineering and specialty consulting firms also provided design services for the project. Most notably, Austin-based Miró Rivera Architects designed the Grand Plaza, the concession and ticketing buildings and the facility's signature buildings: the Main Grandstand and the Observation Tower. Walter P Moore served as overall project structural engineer-of-record, providing the design of numerous structures that were framed in wood, reinforced concrete or structural steel. The identity of the COTA racetrack is certainly established by its steel structures, including the Main Grandstand located at the start and finish lines, the 250-ft-tall Observation Tower and the Grand Plaza, which includes the Amphitheater and Concession roof structures.

Main Grandstand

The nearly 1,200 tons of structural steel used in the Main Grandstand is evident throughout the building and allowed the repetitive linear form of the Grandstand to be developed and constructed quickly in a tight 13-month timeframe, as well as facilitated the design to stay nimble as the final length of the elevated structure along the track evolved.

Located in front of the start and finish lines with views of Turn 1, the Main Grandstand provides seating for more than 9,000 spectators on three levels. An outline of red-painted HSS frames the building and provides a feeling of speed parallel to the racetrack. The ground level houses concessions, restrooms, offices and staff support spaces and features a canopy comprised of white-painted HSS extending out over a row of concession stands to provide shade and define pedestrian walkways. Open-air stairs access amenities on the second floor including a 6,500-sq.-ft lounge and event space, and the third floor hosts

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▲ The Main Grandstand uses 1,200 tons of structural steel...

◄ ...while the Observation Tower uses about 385 tons.

▲ The Circuit of the Americas is the first purpose-built F1 track in the U.S.




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Miró Rivera Architects

▲ The Main Grandstand, under construction.

➤ The observation deck of the 250-ft-tall tower.

▼ Cantilevered steel over one of the concession areas.

Miró Rivera Architects

Michael Hsu | Miró Rivera Architects

a second lounge as well as private suites. A white fabric tensile canopy supported by 3D interlocking cantilevered structural steel trusses, using both rectangular and round HSS, provides shade for spectators.

WPM designed each truss to reach out 50 ft over the spectators to support the tensile membrane. Steel edge cables grip the extreme tips of the truss cantilevers, and steel cable trusses link the steel trusses at their midpoint running parallel to the track. A polytetrafluoroethylene (PTFE)-coated fiberglass tensile membrane clamped to the network of steel cables gracefully sweeps between the spine of each of the cantilevered steel trusses to provide much-needed protection from the Texas heat.

The 11 exposed trusses are spaced at approximately 40 ft apart, and this interval matches the raker frame locations of the building it shades. The raker frames are comprised of W36 members with plate infill at the knuckle intersections, with supporting columns to provide the stiffness that allows the steel to cantilever over ample column-free space below. Traditional composite steel framing infills the elevated floors between raker frames.

Steel braces tie each of these floors together, including many completely visible to the public as they approach the venue on race day. Before they enter the facility, fans pass between HSS blade braces and under an HSS trellis canopy. Outboard of the structure, the HSS blade braces rise more than 60 ft out of the ground. Positioned along the same modular line as the roof trusses and raker frames, these aesthetic elements tie back into the floor diaphragms to become a fully functional part of the vertical lateral load resisting system. Steel tension rods form multi-story X-braces within the window-wall system set back from the blade braces, and the trellis canopy is comprised of small-diameter HSS spaced 1 ft apart that cantilever 30 ft past the blade braces.

Encompassing the entire structure is a soaring series of parallel red steel pipes that launch up the side of the building, race over the top of the roof parallel to the track 60 ft above the ground and plummet back down to earth on the other side of the structure. This element ties the structure together into one form and serves as one of several iconic features of the COTA. Design Data's SDS/2 was used for the detail drawings for the Grandstand.

Observation Tower

Due to the elevations changes and sheer size of the 3.4-mile track, it is not possible to see the entire circuit from a single location at ground level. The Observation Tower was conceived by Miró Rivera Architects as both an elevated race viewing platform and an iconic visual element of the Grand Plaza area of the track. Inspired by the image of red streaks of glowing light that tail lights leave behind in the dark, a fan of red steel tubes over the amphitheater stage converges to form a "veil" that sweeps up and over a central elevator core wrapped by a double-helix stair. Suspended from this pipe steel canopy is a viewing deck that offers a sweeping panorama of the entire track, downtown Austin and the nearby Texas Hill Country from an elevation of 230 ft.

➤ The two stairs of the tower are arranged in double helix fashion, with the continuous steel plate treads and risers coupled with the channel stringers forming the inner layer of the layered diagrid tube.


Paul Finkel | Piston Design

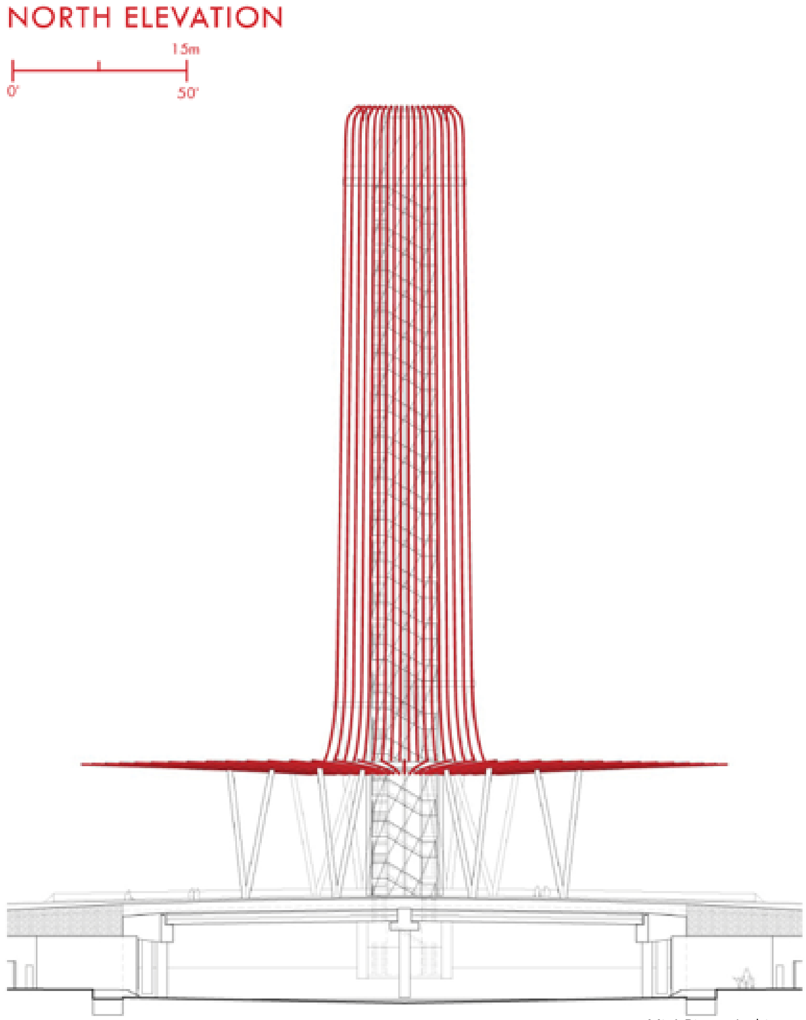
The structural arrangement of the Observation Tower is a result of a meticulous blending of functional, structural and constructability considerations. The tower could best be described as a layered diagrid HSS structure. Interior to the tower's 21-ft by 22-ft trapezoidal footprint, the primary functional elements are a single elevator shaft and a pair of stairs accessing the observation level; the elevator shaft was framed with non-structural light-gage framing and does not contribute to the structural form.

The two stairs are arranged in double helix fashion, with the continuous steel plate treads and risers coupled with the channel stringers forming the inner layer of the layered diagrid tube. Since each helical stair flight is continuous, the width of the stair in the open structure allows the inner layer to function as a continuous diaphragm to distribute loading efficiently to the entire tube system. The second layer of structure is a series of slender HSS3×3 diagonals connected to the outer face of the stair channel stringers. Coupled with the bracing effect of the inclined stringers in the opposite direction, the inner and second layers provide the majority of the tube shear resistance. The outer layer is a series of 17 vertical HSS4×4 columns connected to the outer face of the second layer and providing for gravity and overturning resistance.

The decision to use a network of distributed, filigree structural elements in lieu of fewer, larger members drove the design aesthetic from the outset. Arranging the stairs in a helical fashion provided the shortest consistent vertical dimension between "touches" of the helical diaphragm, which enabled more slender compression members. Additionally, the layered approach was driven by finding a way for the large number of member intersections to occur without the need for passing large forces through one another. Instead, the distributed resistance concept means that the forces transferring from layer to layer at crossing points are rather small and can be handled with unconventional eccentric connections that would not be feasible with larger members.

At the top, the side faces of the layered diagrid tower extend outward to form a deep cantilever truss that supports a 900-sq.-ft viewing deck. A portion of the floor is structural laminated glass, allowing more daring visitors to look 230 ft straight down to the track below. From above this level, the "veil" of closely spaced HSS8.625 rounds cascades down the front of the tower. While ostensibly an architectural feature, the veil also serves as an outrigger column for lateral load resistance via a series of struts and rods that connect it to the main tower. Including all structural steel, floor plating, railings and connections, the Observation Tower contains approximately 385 tons of steel.

Due to the tight 10-month timeframe from owner approval to race day, the tower's design and construction team quickly realized that normal project delivery methods would not be successful. To rapidly convey the complete design of the complex tower structure



Miró Rivera Architects

▲ North elevation of the Observation Tower.

▼ COTA's Austin 360 Amphitheater can accommodate more than 14,000 guests.

Michael Hsu | Miró Rivera Architects

in a way that could be immediately used by fabricator Patriot Erectors, WPM prepared a fully connected Tekla model. Sequences of this model were electronically transferred to Wheaton Detailing Service, who then produced shop drawings directly from the model. The construction manager, Austin Commercial, estimated that the integrated delivery process saved three months over a more conventional process.

The Observation Tower was erected by assembling complete 24-ft-tall sections in multiple casting beds on the ground, then stacking these sections vertically by crane lift. The veil was then attached to the side of the structure working up, and the top was crowned by the cantilevered truss section.

Grand Plaza

Turns 15 through 19 of the circuit form a horseshoe and surround the 27-acre Grand Plaza, which serves as the main entry for most visitors and contains a box office, reflecting pool, Great Lawn, concessions and outdoor dining spaces; the Austin 360 Amphitheater and Observation Tower define the southern edge of the plaza.

The concession buildings were designed to provide not only the enclosed space required for services, but also large advertising surfaces. The concessions follow the module defined by the Grandstand to provide architectural continuity across the facility. Each 80-ft-long concession building contains three 12-ft by 65-ft-tall braced frame "blades" that are wrapped with banners appropriate to each event. Between each blade and set back 12 ft from the blades, the orthogonal braced frame provides two 40-ft by 36-ft surfaces that can also be sold as advertising space.

Each concession also has a canopy of small-diameter HSS that cantilever 30 ft from the concession roof. The canopies consist of a 12-ft-long, 1.5-in.-diameter standard HSS sleeved into 2.875-in.-diameter HSS. The sections are spaced at 1 ft on center and the first 8 ft of the canopy supports L2×3 angles that sit on top of the sections to enhance the shading closer to the serving counters.

The architects wanted a design that expressed the gentle curve of a member deflecting under self-weight and that was simple to construct. The concession roofs are concrete slabs on cellular metal deck, the weight of which is used to help counteract overturning forces due to the long cantilever. The larger pipe is cast into the

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first 8 ft of the cantilever slab to transfer bending forces from the HSS into the slab. The transition from the larger to the smaller pipe was accomplished by inserting the smaller HSS into the larger HSS and filling the annular space with construction adhesive, allowing adjustability to ensure the HSS tips aligned and minimized the need for field welding. The cantilever HSS deflect well in excess of the traditional $1/240$ deflection ratios and provide a dramatic overhang while waiting for refreshments.

Austin's official motto has long been "Live Music Capital of the World," and the Austin 360 Amphitheater at the south end of the Grand Plaza brings that aspect of the city to its new racetrack; it is also now Austin's largest permanent outdoor music venue. While the city has many outdoor festivals on temporary stages, it previously did not have a permanent outdoor venue capable of hosting major touring acts. The amphitheater has 6,500 fixed seats and can hold more than 14,000 guests.

The stage roof consists of nine primary trusses supported by transfer trusses spanning to four trussed towers. The top chords of the trusses are red 8-in. standard HSS that are extensions to the veil of the observation tower. The stage is covered by a transparent single-layer ETFE membrane with integral stainless steel cables just above the plane of the truss top chords. Between each truss chord are two additional infill pipes to match each member of the tower veil and provide the effect of the veil extending out over the stage. The infill members are connected to the truss top chords by a checkerboard of HSS6×4 that both support the infill members and develop a horizontal vierendeel diaphragm. The primary structure supports a 70-ton concert rigging grid integrated at the bottom chord level of the trusses and accessed via a front of stage catwalk system.

To enable shipping to the project site the planer trusses were shop fabricated independent of the infill panels. However, because all of the steel is exposed to view, the conventional shop weld-field bolt connection philosophy was slightly modified. Bolted connections were used on secondary members and where members were not in full view. Field welded connections were used in the other locations, but connection designs were such that groove welds and overhead welding were minimized.


Miró Rivera Architects

Finish Line

On November 18, 2012 the Formula 1 United States Grand Prix was held at the new 20-turn, 3.4-mile COTA. Over 117,000 race fans were in attendance on a beautiful, cloudless Austin day to witness the race (won by Lewis Hamilton of the Vodafone McLaren Mercedes team). Total attendance for the three-day event was over 265,000, which included fans from around the world. Additional race events in 2013 and beyond include Grand-Am, MotoGP, American Le Mans Series, Australian V-8 Supercars and the World Endurance Championship. The presence of the Amphitheater also transforms COTA into an entertainment venue hosting weekly events, ranging from Mumford and Sons to Iron Maiden. The steel-supported venue is currently competing to host the X Games and will continue to attract a variety of world-class events to central Texas. MSC

Owner
Circuit of the Americas LLC, Austin

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Miró Rivera Architects, Austin

Structural Engineer
Walter P Moore, Austin and Dallas

Construction Manager
Austin Commercial, Inc., Austin

Steel Team for Main Grandstand and Other Structures

Fabricator
Alpha/SteelFab, McKinney, Texas (AISC Member/AISC Certified Fabricator)

Detailer
Alpha Fabrication Services, McKinney, Texas (AISC Member)

Erector
Derr Steel Erection Company, Euless, Texas (AISC Member/AISC Advanced Certified Steel Erector)

Steel Team for Observation Tower and Other Structures

Fabricator and Erector
Patriot Erectors, Inc., Dripping Springs, Texas (AISC Member/AISC Certified Fabricator and Advanced Certified Steel Erector)

Detailer
Wheaton Detailing Service, Spring, Texas (AISC Member)