



# What's COOL in STEEL

Zachary Wasserman



## COOL STRUCTURES

## Desert Art

BY GEOFF WEISENBERGER

**FOR MANY OF US**, a minor in our undergraduate studies is a way of staying attached to or learning more about a field of interest. Or it's a back-up plan to our major. Or a resume-builder. Or a creative outlet. Or a way to seem more well-rounded.

Or in the case of Corbett Griffith, who graduated at the top of his mechanical engineering class at Georgia Tech while minoring in sculpture, it's a way to combine the artistic with the practical into a unique job. Griffith is the president of Instinct, a Bay Area-based design and engineering company that creates physical products and sculptures from conceptual designs ([www.withinstinct.com](http://www.withinstinct.com)). He describes himself as a mechanical designer that can interface between artists and structural engineers—a “sculptor consultant,” if you will.

“I begin with the artists and their ideas,” Griffith explains. “I work to develop a framework around their concepts instead of running them over with engineering. I think of my work as building kits for artists, like erector sets out of monumental steel. They come to me with a concept, and I deliver a truckload of custom steel and a set of assembly instructions.”

## BURNING MAN

For the last few years, Griffith has tapped into his artistic and engineering knowledge to create fascinating, complex, strangely beautiful—not to mention huge—steel sculptures for the annual Burning Man festival; the weeklong event takes place around Labor Day weekend in Black Rock City, a temporary city in the Nevada desert, and is dedicated to community, art, self-expression, and self-sufficiency ([www.burningman.com](http://www.burningman.com)).

Griffith's first sculpture for Burning Man (2003) was the Temple of Gravity, which he describes as a “modern-day Stonehenge.”

The sculpture was his senior design project at Georgia Tech. The 80-ton installation, designed by Atlanta-based sculptor Zachary Coffin ([www.zacharycoffin.com](http://www.zacharycoffin.com)), is an open-air dome of curved steel. The structure, 50 ft in diameter and 21 ft tall, consists of five round steel tubes (schedule 40 steel pipe) that connect at a central point and bend down to five slabs of granite (13,000 lb each) on the ground. Slabs of granite (17,000 lb each) are also suspended, one each, by chains from the steel tubes, and people are able to climb on the suspended slabs and rock them back and forth.

In 2005, Griffith brought another of Coffin's ideas to life at Burning Man in the form of Colossus. Smaller in weight (20 tons of steel) but taller in height (70 ft), this sculpture is similar to the Temple of Gravity in that it suspends rock—15 tons of it—from three steel “arms” that bend toward the earth. Each of the three rocks hang from the armature in a different way. One is suspended from a hanger so it can swing back and forth, one is on a bearing so it can spin around, and the last rock is stationary and flat. Another similarity Colossus shares with the Temple of Gravity is that it too is set in motion by people; ropes attached to the suspended boulders allow people to rotate the metal and rock, providing quite a workout.

“My design sense flows from both the aesthetic of the piece and the fundamental engineering problem at hand. I try to let the aesthetics guide the engineering as much as possible.” says Griffith. “On Colossus, I began with an artist's rough drawing. He envisioned the feel of the piece. Through a number of revisions, I developed the look and construction scheme, and fleshed out the concepts with engineering. This ended up dictating the majority of the end experience with the sculpture.”

**left page:** Steampunk Treehouse, designed by Sean Orlando and crew.

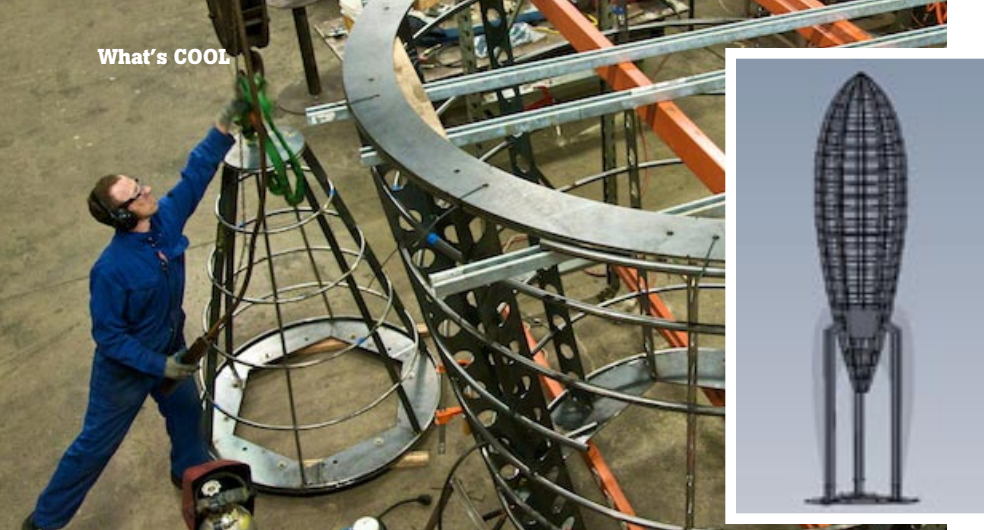
**this page:** Temple of Gravity (left and center) and Colossus (right), two projects that Griffith assisted artist Zachary Coffin in bringing to life.



Keith Helfrich (left, center)



Daniel Bauen



Raygun Gothic Rocketship will premiere at this year's Burning Man festival.

Nick Winterhalter (left); Instinct Design (right)

## OF DERRICKS, TREES, AND ROCKETS

Besides Coffin, Instinct has built Burning Man sculptures designed by several other artists as well. Crude Awakening, which debuted at Burning Man 2007, is a 100-ft-tall wood and steel oil derrick that was detonated with 3,000 gallons of jet fuel and propane (designed by artists Dan Das Mann and Karen Cusolito).

"In the case of Crude Awakening, the concept was nearly finished but needed my insight in fabrication to design a set of interlocking steel joints for the cross bracing," says Griffith. "Also, designing a flight of stairs that follows the inside walls of a pyramid is no simple task. We ended up fabricating custom steel brackets to attach the stringers to the tower framework and supported the landings from steel cables." (Structural engineering advice for this project, as well as Griffith's latest project—discussed below—was provided by Mark Sinclair of structural engineering firm Degenkolb.)

Steampunk Treehouse, a metal tree with a wood and metal house perched in the branches, is another one of Instinct's jobs that appeared at the 2007 festival. Designed by Sean Orlando and crew, the sculpture is exceptionally complex, with a trunk and branches made of twisting steel pipe trusses. According to the official web site for the sculpture ([www.steamtreehouse.com](http://www.steamtreehouse.com)), the three main load-bearing branches were fabricated as separate units and bolted to the tree trunk with flange plates and ¾-in. bolts. The house is built on a 10-ft by 15-ft dual square tube frame with a ¾-in. plywood floor in a circular pattern at the house level (approximately 15 ft from the ground). The lower section of the branches is welded to the trunk while the upper branches bolt to the lower section using flange plates for ease of transportation. The lower steel frame is welded to the upper gussets of the trunk, and the upper steel frame, with house attached, is bolted to the lower steel frame. The main structure of the house is wood, reinforced with a steel sub-structure that ties the three branches and the house together for added support.

Instinct's latest Burning Man mega-sculpture, to debut at this year's festival (August 31-September 7) is the Raygun Gothic Rocketship ([www.raygungothicrocket.com](http://www.raygungothicrocket.com)). Designed by Sean Orlando, Nathaniel Taylor, David Shulman and Crew, the 40-ft-high gothic-styled rocket ship is framed in steel and clad with aluminum and copper. The piece was built, detailed, and output in only 16 hours of Solidworks 2009 seat time. "A new personal record for art to parts to art!" says Griffith (Solidworks is his current go-to software for detailing large-scale sculptures).

Crude Awakening at the 2007 edition of Burning Man.

#### VOLUNTEER WORK

It takes more than just an artist and an engineer to put these large-scale sculptures together. Volunteers typically perform the steel fabrication as well as the erection; teams of up to 100 volunteers, led by the artists, build them onsite. In addition, volunteer certified structural welders are used for the critical joints.

After Burning Man, the sculptures tour other festivals, are stored for future use, or find permanent homes—e.g., Temple of Gravity is currently installed at We Care Spa in Palm Springs, Calif. But Burning Man is the launch pad for these innovative works, thanks to its celebration of creativity and artistic fervor.

“Burning Man has been a great playground and sand box for ideas,” says Griffith. “The sculptures I’ve developed for the event have been as much a design challenge in construction and fabrication as they are an essay on the art of engineering and the beauty of structures themselves.”

“In one week’s time you assemble, display, and remove your piece. It’s a strange place to build. In what other job do you have to battle 100-mph winds, blistering heat, undressing muses, and serious techno music to get access to a crane?”



Courtesy of Instinct Design





Photos on this page: Iwan Baan © 2009

COOL PARK

# Elevated Experience

BY CRAIG SCHWITTER, P.E., BURO HAPPOLD

**JUNE MARKED THE OPENING** of a new public green space on Manhattan's west side: the approximately ¼-mile long High Line Park. And it certainly lives up to its name, seeing as it was built 30 ft above the street.

The project transformed an outdated, early 1930s elevated train line, framed in steel, into an attractive new public park that appears to float in midair. Two structural engineering firms contributed to the project. Buro Happold North America was responsible for the structural engineering in support of the new landscaping

and architectural components, as well as the MEP engineering and waterproofing. Robert Silman Associates provided structural engineering services to stabilize the existing structure.

The challenge for Buro Happold was to design new structural elements while making adjustments to and maintaining the historic look of the original steel structure. The existing High Line structure, which once moved trains, was robust. However, its steel structure had riveted connections, which made changes difficult. To insert the new components of the

Manhattan's High Line Park used existing and new structural steel to turn an old elevated train line into a modern, unique public space.

landscape architecture and architectural design, we had to cut into steel girders and add numerous components. We also added drains, elevators, electricity, and utility rooms.

To support the landscaping and new architectural elements, our engineers cut into the existing steel girders to insert openings for staircases that provide stair access from the street to the elevated park. They also inserted expansion joints to coordinate structural shifts and avoid conflicts along the length of the High Line between the existing steel



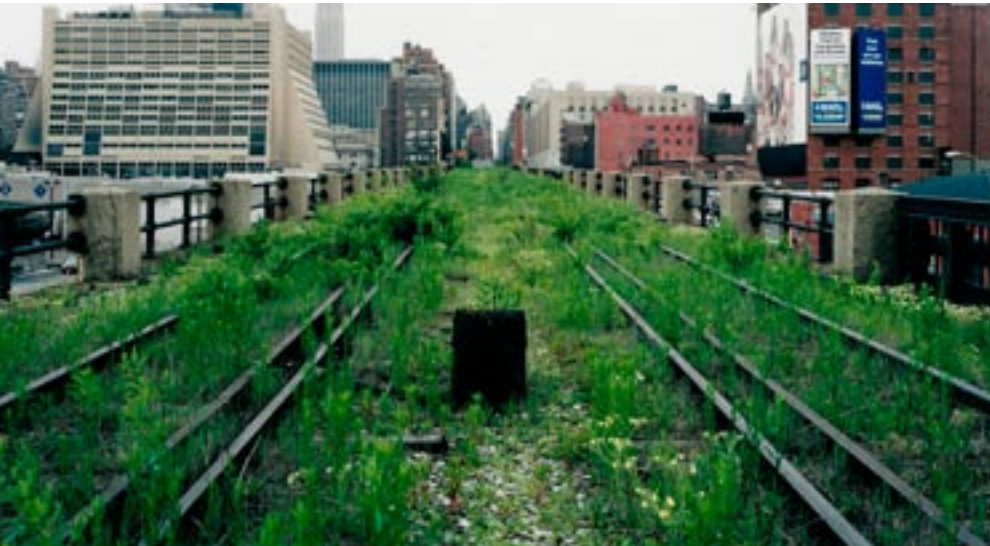


structure and the precast concrete slabs forming the new pathway. Expansion joints in the exposed steel structure of the High Line are spaced approximately at 138-ft intervals. The anticipated movement of the structure due to thermal changes is  $\frac{3}{4}$  in. between the joints; to accommodate this movement in the planks, expansion joints were inserted at approximately the same locations as in the existing structure. The geometry and interlocking layout of the planks, however, dictated that the plank joints needed to be staggered, with planks supported on neoprene bearing pads to accommodate the movement.

The design also called for removal of significant areas of a 10-ft-deep girder that spans 10th Avenue to create large glazed picture windows, as well as the removal of existing slabs and beams, to incorporate a new terraced platform for passive recreation. Also, a water tank supported above 15th Street by supplementary steel framing attached to the High Line stringers stores 2,900 gallons of water for a water feature along the 100-ft

sundeck, which has movable lounge chairs and unobstructed views of the Hudson River. In addition, we designed a drainage system under the soil to support the plantings and new landscaped areas, which are complemented by an irrigation system. We also created an intricate waterproofing system to protect the facilities and streets located under the High Line from possible leaks.

This portion of the park is just the first of several phases. Construction for the landscaping phase of the second section is about to commence and will likely extend over an 18-month period. The site preparation for this section was executed during construction of the first section of the park and involved removal of the old track and ballast, repairing the steel and concrete deck, and preparing it to receive a new waterproofing membrane. When Section 2 is complete in 2010, the High Line will be a mile-and-a-half-long elevated park, running through the western Manhattan neighborhoods of the Meatpacking District, West Chelsea, and Clinton/Hell's Kitchen.



Joel Sternfeld © 2000



Courtesy Buro Happold

A view of the 10th Avenue Square portion of the project, with the pre-existing slab removed. Bleachers overlooking the street were being installed at this point.



All images: Courtesy Miró Rivera Architects

COOL RESTROOM

# The Call of Nature

BY MIGUEL RIVERA, AIA, AND JUAN MIRÓ, AIA, MIRÓ RIVERA ARCHITECTS  
PHOTOS BY PAUL FINKEL/PISTON DESIGN

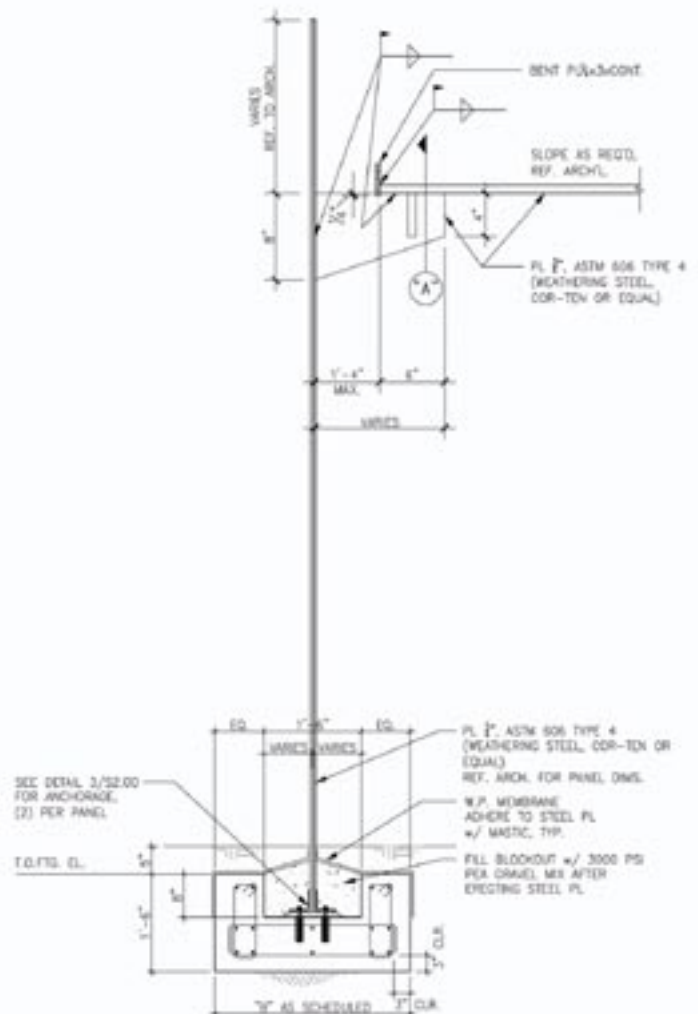
**THE LADY BIRD LAKE HIKE AND BIKE TRAIL** is a linear park of scenic trails and landscaping that winds its way along the banks of the Colorado River in downtown Austin. The park, very popular among runners and bike riders, provides residents and visitors with a rural escape in an urban setting. It is also home to a small, yet impressive, public restroom.

The first public restroom built in the park in more than 30 years, it was designed by Miró Rivera Architects. It consists of 49 ¾-in.-thick vertical weathering steel plates whose widths and heights vary from 1 ft wide by 1.5 ft high to 2 ft wide by 13 ft high. The panels are arranged as a “spine” that begins elongated at one end, then tightens into a circle at the other to form the walls of the restroom; the pattern resembles an inverted, stretched-out number 6—or 9—from the air. The plates are staggered in plan to control views and to allow the penetration of light and fresh air. Both the door and roof were fabricated from ¾-in.-thick steel plate. L4x4s are welded to the bottom of both sides of each panel. Anchor rods attach the angles to the trough portion of the grade beam, and the trough is back-filled with concrete.

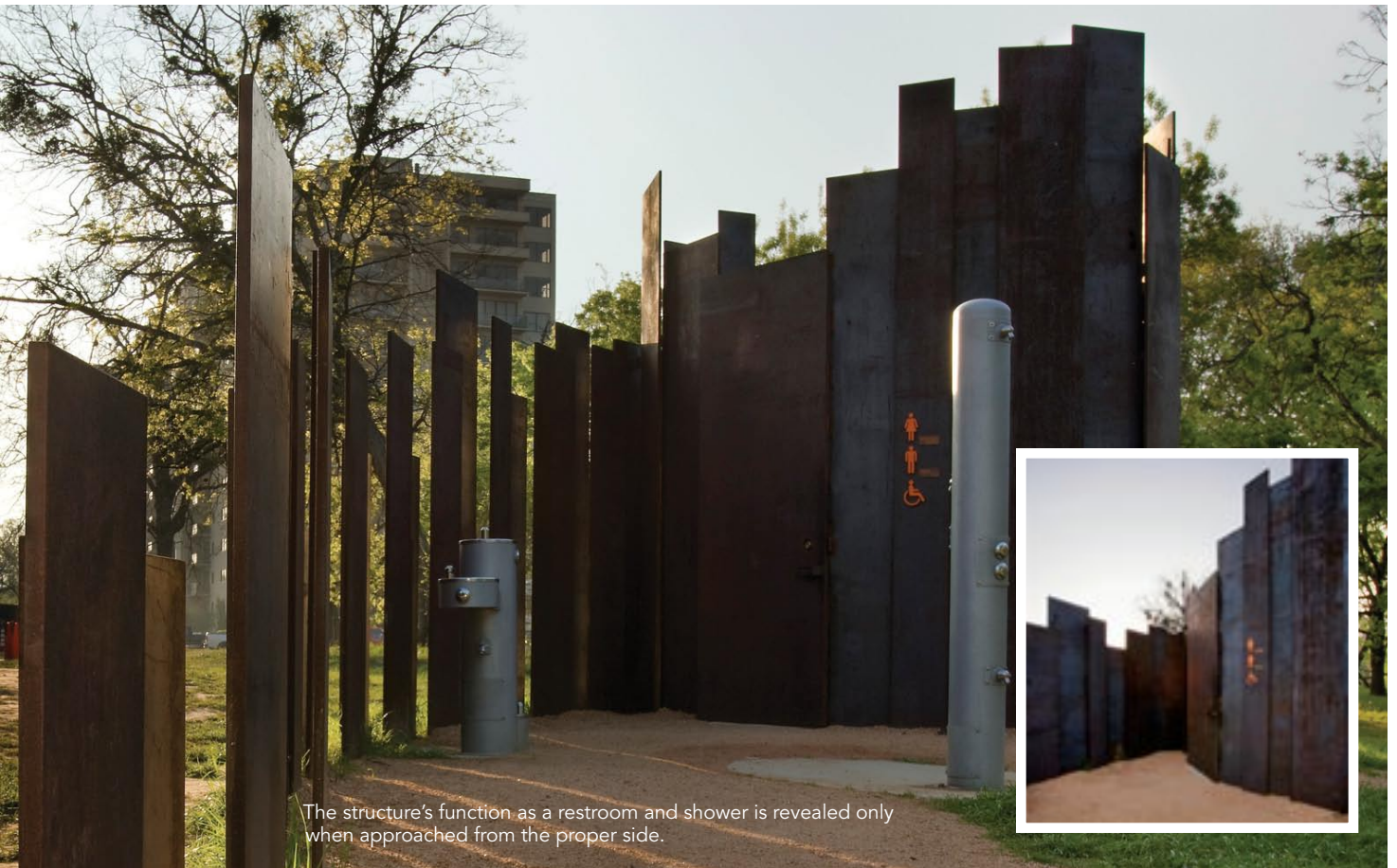
The restroom is handicapped-accessible and—in addition to a commode, urinal, sink and bench inside—includes a drinking fountain and shower outside. It also requires minimal maintenance; the plumbing fixtures are made from heavy-duty stainless steel, there is no need for artificial light or mechanical ventilation inside, and the weathering steel panels will weather naturally over time, creating an ever-changing sculpture that combines form and, quite literally, function.

**above:** The plates’ dimensions range from 1 ft wide by 1.5 ft high to 2 ft wide by 13 ft high.

**right:** Detail of the bracing of one of the steel plates.







The structure's function as a restroom and shower is revealed only when approached from the proper side.





COOL HOUSE

## Green—and Big Bad Wolf-Proof

**THE BIG, BAD WOLF** was able to blow down the straw house with ease. But what if the straw house had been framed in steel?

While a straw house may bring up thoughts of the “Three Little Pigs,” buildings insulated with straw bales began appearing in real life in the 1900s. Straw is natural and renewable and provides tremendous insulation value. Most straw houses use wood framing; Hakata House, designed by Vestal, N.Y.-based architecture firm Secret Base Design, is a steel-framed structure that uses bales of straw for infill and insulation.



Steel and straw work hand in hand in Hakata House, a single-family residence in Upstate New York. Completed project, above; steel framing, below.

Photos: Courtesy Secret Base Design

Straw helps fill in the gaps; the bales were shaped to fit around the steel columns.

Sustainability was a key goal of the project. Secret Base recognized the green advantages of steel; the steel for the frame used certified recycled content and was produced regionally, supporting the local economy and reducing shipping. Secret Base also based its decision on the fact that the steel frame provided for a much larger roof span as well as longer spaces between the posts; with fewer posts, there was less fitting of bales around the structure. The house uses a traditional steel frame structure; the bales were shaped to fit around the columns.

The line of structure for Hakata House is on the inside of the wall, so the exterior is a continuous line of bales, which provided optimal insulation value. Door and window openings were set to the outside of the wall to create deep window seats or sills, which resulted in better protection from water infiltration at these connections. Secret Base has designed and built four other more conventional straw buildings, but the steel frame of Hakata House is what makes it unique.

Having straw as an interior wall offers flexibility in terms of finish. It can be smooth and level, undulating, or bumpy depending on the desired look. For a smooth wall, the bales can be trimmed prior to plastering; undulating walls occur naturally, and curvy walls can be stacked irregularly or shaped after. In the case of Hakata House, both the interior and exterior walls were covered with a natural lime-based plaster.

The interior steel framing was left exposed in some areas and either painted or finished. Not only did this “honest approach” create the desired modern, industrial appearance, but also by eliminating extra finish materials, the cost and ecological impact were greatly reduced.

Aside from using steel and other materials/tactics geared toward sustainability—local wood, recycled content carpet, refurbished tin ceilings in the kitchen, soy-based insulation, low-VOC sealants, etc.—another notable element of the house is the “truth window,” a tradition with straw bale structures. This small, wooden door on the inside of one of the exterior walls opens to reveal the straw behind the plaster.

While steel and straw seem to be on opposite ends of the material spectrum, they were able to join forces in an efficient, stable, and sturdy way in Hakata House—and helped make one straw house that is impervious to the Big Bad Wolf.

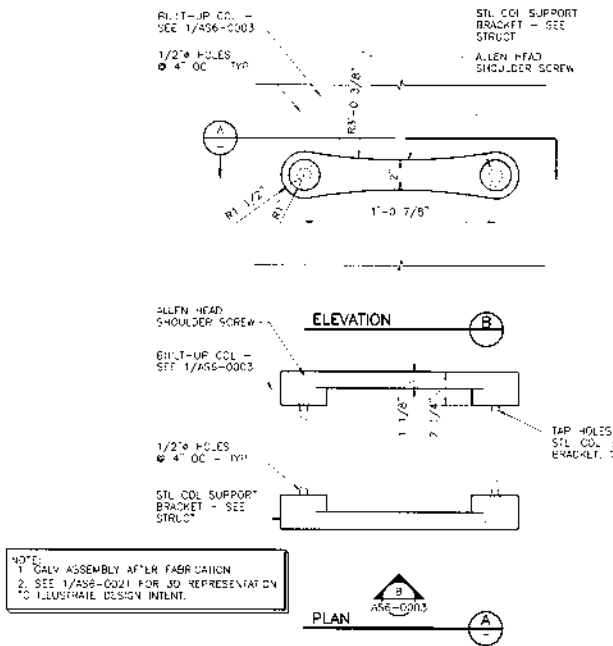




COOL SUN SHADES

# Beating the Heat

BY JEFF CARPENTER, BIRDAIR, INC.



left: A detail of one of the built-up columns.

Photos: Courtesy Birdair, Inc.

above photos: Canopies like these—roughly 560 of them—dot Phoenix's mass transit landscape, providing shade from the intense sun.

**LIVING IN THE VALLEY OF THE SUN** doesn't mean having to bask in the relentless rays all day long. And thanks to a series of open-air shelters at stops along Phoenix's Valley Metro light rail line and bus routes—there are about 560 canopies spread over roughly 50 stations—commuters can wait for their trains without having to apply sunscreen.

Framed in steel and adhering to AISC architecturally exposed structural steel (AESS) standards, the shelters' signature elements are sun canopies composed of round hollow structural section (HSS) "arms"—5-in. Std. Pipe (CHS 5.563 x 0.258)—that support polytetrafluoroethylene (PTFE, commonly known by the brand name Teflon) membranes. Each arm has "fins" that make the cantilevered elements more efficient for the unique type of loading they endure. Tensile membranes support all of their loads in tension within their own plane. In other words, external loads on the canopies not only resolve to be vertical loads on the steel, but also some additional loads applied to the steel in the plane of the fabric. These additional loads are some nonlinear factor of the gravity and wind loads (evaluated via nonlinear FEM analysis) and depend on the stiffness, deflection, and prestress in the membranes. Because these types of structures are typically designed to accept some type of conventional "hard deck" roof that automatically resolves their loads directly to the supporting steel, this "side load" factor was probably not considered in the architectural design phase. As a result we decided to use the architectural fins near the column supports to provide added in-plane stiffness to the arms by having them partial-penetration-welded to the support saddles. Also, the membrane roof structures generally end up having lesser vertical loads than conventional roofing materials because they are lightweight—which also makes them a good choice for long-span roofs.

Cast "saddles" connect the arms to the steel columns, and careful attention had to be paid to the welding, due to the relatively thin (0.258 in.) walls of the arms. In addition, special "bullet ends" for the end of each arm were pressed to the required shape in an

attempt to save on cost and materials, as this avoided the need to machine thousands of parts from solid bar stock—and also created an additional bit of architectural flair.

The unique shape of the structures called for continuous curved helical plates bent to a slight helical shape for the attachment of the fabric. The "knife plates" at the bullet ends were slightly oversized to facilitate welding of the bullet halves. The cable terminations were specially designed and customized to comply with both the architectural intent of the knife plates and the hole size (3/4 in.) that the fabricator could use most efficiently with a punch operation. Weight—including the arms, cable, and membrane—for the larger canopies was roughly 1,000 lb and about 750 lb for the smaller ones.

While Josserrand Construction Company (the erector) devised its own erection template based on geometry provided by Birdair, Inc. (the maker of the PTFE membranes), the erection sequence itself played an important role in the design phase. The tensile canopy arms had to be neatly connected by fastening the arms' supporting saddles through a column to the other side where there would be a "dog-bone" connection or another saddle (depending on where the canopy was in the sequence). By design of an intricate system of threaded rods, jamb nuts, heavy hex nuts, and shim and spacer plates, the team was able to come up with a non-obtrusive solution for the connection that was so efficient that the entire tensile system could be tensioned to the full prestress value just by tightening a few nuts. A pneumatic wrench was used to hasten that process, although it could have been done via manual torquing alone. The system allowed for coordination and tolerance allowance with other steel elements such as the supporting columns and their dog-bone connections, and the spacer plates eliminated some special machining of the saddles.

While relatively small structures, the Valley Metro shelters are innovative when it comes to connections, graceful when it comes to aesthetics, and much-appreciated when it comes to providing some relief from the hot sun.

## COOL TABLE

## Under the Table

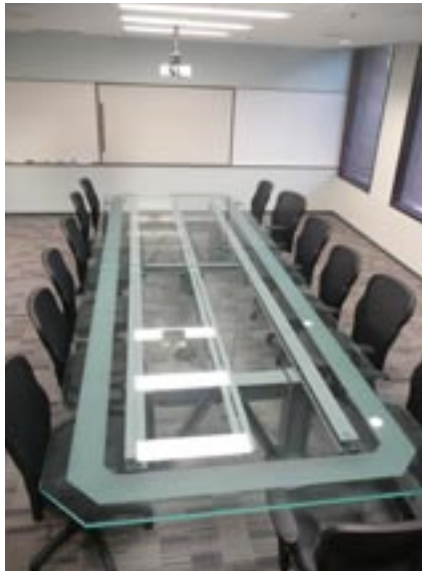
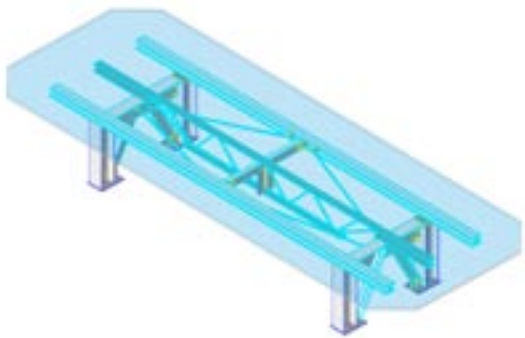
BY WILLIAM P. JACOBS, V, P.E., SDL  
STRUCTURAL ENGINEERS

**DURING OUR RECENT OFFICE RENOVATION** in Atlanta, SDL Structural Engineers decided that a standard conference table was not adequate to truly complement our chosen profession; we needed structural steel! Inspired by a smaller table in the Structures Laboratory at Virginia Tech, the resulting design easily accommodates 16 people and provides a focal point that is both functional and a conversation piece.

The table is supported on each end by a concentric braced frame ( $R=3$ , of course) made up of MC3x7.1 bracing members and W6x15 verticals. Spanning between these frames on each side are two sets of MC3x7.1 channels connected together to form wide-flange shapes. The center load-carrying mem-

ber is a 12K1SP joist that was generously donated by Nucor-Vulcraft. (The "SP" designator indicates that the joist was designed for both uniform loading and for two traveling 250-lb point loads—in case a meeting gets out of control). Connections were field bolted with ½-in.-diameter A307 bolts.

The structural glass top surface is composed of two pieces, each ¾ in. thick, with an overall dead load of 1,000 lb. An etched band was added around the perimeter to complete the design. In order to visualize and detail the table for construction, a complete structural model was created in Revit Structure. MSC



Images : Courtesy SDL Structural Engineers