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STEEL DAY 2009

The Amazing **Steel Structures** of **Millennium Park**

The 1998 Millennium Park plan replaced unsightly parking lots and working railroad lines with an underground parking garage capped by a green park and bordered by a cliff wall of buildings to the west and north, parks and the lake to the east, and the Art Institute to the south. (Is this the world's largest green roof?) Creating this 25.4-acre park also fulfilled Burnham's 1909 plan to extend Grant Park to the north. The gift of a music pavilion from the Pritzker family, however, began a chain reaction that would transform the park from a ho-hum repeat of grass and flowers into a treasure trove of world-class art and architecture including some spectacular steel structures. Not surprisingly, these steel forms presented significant design, fabrication and erection challenges. This guide celebrates the achievements of all those who helped create these marvelous metal structures.

come celebrate STEEL DAY 2009!

by George Wendt

Chicago Metal Rolled Products
Curving Steel Since 1908
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Starting at the northwest corner of the park, proceed east to the **Jay Pritzker Pavilion**.

The Jay Pritzker Pavilion:
Tresses and a Trellis

Talk about a challenge! Architect Frank O. Gehry's signature curvilinear elements soar 120 ft in the air while cantilevering 130 ft from the stage. (A cantilever is a structural element supported on only one end—think diving board.) Skidmore, Owings & Merrill (SOM) engineers calculated not only the forces of the wind on these "sails" but also the rigidity required to avoid wind-induced flutter. A criss-crossing network of tube and beam struts and trusses anchored in concrete provides the mountings for the stainless steel cladding of the sails. 3D modeling using CATIA software established a spatial grid work to guide LeJuene Steel, the fabricator of the supports. A. Zahner Company also used this software to cut the shingles each of which is different. All the curves in the elements are actually composed of segmented straight sections. Alternately referred to as a "massive, metal headdress," "a bow of curled ribbons on a gift box," and "a flashy, silver lion with an unruly mane," this band shell with its curlicue tresses functions as the focal point for the 11,000 viewers who can enjoy each free concert in the park.

Gehry also designed a silver trellis of 12-, 14-, 16-, 18-, and 20-in. diameter pipe from which to hang speakers without obstructing anyone's view and to create a "room," which is the size of four football fields for the concerts. A system which delays the sound by milliseconds as it is distributed mimics the sound of a concert hall.

Gehry's original trellis model had pipe curved with multiple radii and in two planes. Thanks to the opportunity for early involvement with the design team, Chicago Metal Rolled Products suggested bending in one plane and changing radii only at the nodal junctions. Gehry and SOM agreed and decided to tip each arc on its side. John Zils of SOM said these suggestions were a "major breakthrough from a fabrication and cost-reduction standpoint." On one of the largest bending machines in the world, Chicago Metal bent all the pipe to a curvature within ⅛ in. tolerance over 20 ft.

The trellis is 625 ft long, 325 ft wide, and 60 ft at its highest point; the radii range from 100 to 1,000 ft. Twenty-four arches, one flatter and one steeper, spring from each pylon and land on pylons "downstream" on the other side. Intersecting arches meet on the same surface but at different angles.

All fabrication called for Architecturally Exposed Structural Steel (AESS) quality, technology to curve 570 tons of large pipe affordably without distortion, a timely delivery (e.g. expediting the X node where the trellis meets the elements above the stage), and precise fabrication of the nodal junctions by Acme Structural, the structural steel fabricator.

Danny's Construction erected both the trellis and the stage using cranes and 78-ft-tall shoring towers. The towers allowed for subtle location adjustments and welding of all the structural sections for the trellis.

The crane required for the pavilion was so large that it had to be disassembled on Columbus Drive, lifted onto a mat that would transfer the load to reinforced columns in the parking lot below, and then reassembled.

After erecting the stage, when the supports were removed from the uppermost pieces of the headdress, the vertical deflection was only ⅜ in.—a tribute to the design, fabrication and erection of the pavilion. Moreover, due to construction restraints, the trellis was built simultaneously from the north and from the south and still fit up perfectly.

The trellis defines the space, supports the speakers, and is one with the work of art that is the Jay Pritzker Pavilion.

Above: Giant rolling machine (Section Modulus 300 $in.^3$) at Chicago Metal Rolled Products curved 570 tons of 20-,18-,16-,14-, and 12-in. diameter pipe for the trellis.

Below: Welding 130 TYK joints at Acme Structural who fabricated the trellis.

Above: LeJeune Steel fabricated the structural framing for the "sails" above the stage, the X node of curved pipe was erected, and then the stainless steel cladding by A Zahner Co. was attached.

Below: Danny's Construction used 48 78-ft-tall shoring towers to erect the trellis and a heavy crane for the stage and elements.

Proceed south along the **Jay Pritzker Pavilion** until you see **Cloud Gate** (aka "**The Bean**") on your right.

Cloud Gate:
Liquid Mercury

Artist Anish Kapoor's complex shape called for a mirror finish that would reflect the city, the lake and viewers as they walk up to the cloud-reflecting sculpture, pass through the "gate" and discover their own reflection in the "belly button" of the cloud shapes. Performance Structures, Inc. (PSI) of California, with the help of MTH of Chicago, accepted the challenge of fabricating and erecting this 30-ft-high, 60-ft-long, 300-ton sculpture, one of the largest in the world.

PSI designed and formed 128 car-sized plates within 0.01 in. of the required dimension on a device similar to ones used to form fenders on automobiles. The plates were then welded to trusses to hold their form for the trip to Chicago. Because the assembled structure would be too heavy to move over the parking lot, the majority of the welding had to be done on site. In fact, a 30,000 lb steel frame about 14 in. below where you stand spans the Park Grill, underground parking, and railroad tracks to support this work of art.

The relatively thin shell of the structure—¼ to ⅜ in. thick—is actually suspended on two giant rings mounted on vertical beams arising from the underground steel frame. Like pant suspenders, springs, struts and cables attach the plates to the rings resulting in 0/0 clearance: the plates came together with a closed edge. Hung this way, the shell does not have to support its own weight.

The structure was assembled on the jobsite with an elaborate rigging system that supported the internal trusses, the plates, and even the erectors, welders and polishers.

The full-penetration, plasma weld seams had to be done from the outside. A flexible track with suction cups guided a traveling torch to cut a keyhole through the abutting pieces. As a mechanism feeding wire followed into the heat zone, the wire melted and then became the weld joint. To shield the weld, a channel on the back side of the plates was filled with gas during the process. The curvaceous shape required all-position welding in the same run, i.e., a single weld pass might start out across a flat surface then proceed downward then overhead and then upward. Because the welding process tends to pull the adjoining plates inward, the engineers developed a process of pushing the edges of the plate a few thousands of an inch out resulting in a smooth seam with no indentation.

The fabricators and erectors developed a 12-step process to bring the 316L stainless steel with a 2B finish to a Mirror #8 finish. Each square foot of surface required 12 to 14 hours of grinding and polishing. When the park opened, the seams were barely visible, but the final polishing had not been completed.

The sculpture can be accessed through the top of the omphalos, the raised structure within the base of the "bean." While under the structure, look carefully and you might see an approximately 3-ft-diameter ring in this "belly-button of the belly-button." Battery-powered devices inside measure the temperature and strain of the sculpture. As of a year ago, no significant movement was detected. Engineers also considered using various frequencies to keep pigeons away but abandoned the idea when it was discovered that these frequencies might actually damage the welds.

Nobody doesn't like "The Bean."

Stainless steel plates were formed and braced at PSI in California.

The mirror finish requires 12 to 14 hours of grinding and polishing for each square foot.

O-shaped rings form a base for the pipe truss system and plates erected by MTH.

The erecting started with the omphalos or "belly button."

Courtesy Performance Structures, Inc.

From **Cloud Gate** walk back east to the **Nichols Bridgeway**.

Nichols Bridgeway:
Architecture that Rises to the Level of Art

Nichols Bridgeway rises with a 5.6%, ADA-compliant slope from deep in the park to connect 60 ft above grade on the third floor of the Modern Wing of the Art Institute and will help drive traffic to a new restaurant and sculpture terrace on the roof as well as to the museum itself. The 15-ft-wide walkway with LED lights under the handrails will be heated in winter to remove ice and snow. The bottom of the bridge is uplit.

Renzo Piano designed both the bridge and the museum. A stark contrast to Gehry's snaky bridge which we will see later, this structure is modeled after a sleek racing yacht: both ends of the bridge are shaped like the prow of a ship. The steel structure is a box truss with a curved bottom steel plate covered by a soffit plate that is also structural. Plate stiffeners inside connect the flat top with the curved bottom. On a very heavy plate roll, Chicago Metal Rolled Products curved 112 pieces of ⅜-in. and ⅝-in.-thick plate to a 10-ft radius in sections as wide as 12 ft and from 12- to 18-ft long taking great care with polished rolls and nylon slings not to scratch any surface.

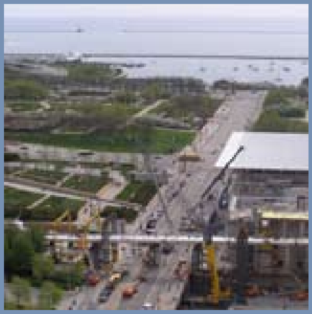
A 10-ft-long mockup was hoisted to where the bridge would meet the Modern Wing so that the architect could study its appearance including the welded and bolted seams. Piano approved the bridge section after viewing in the daytime and uplit at night. Industrial Steel Construction then fabricated eight bridge sections in a manner to conceal the weld splices while also creating a 2,000-ft-radius camber. Engineers from Ove Arup & Partners calculated that the thermal movement of the 620-ft-long bridge would be 2½ in. in either direction and designed the five supports in the park accordingly. Sections from 70 to 90 ft in length were then fabricated and shipped to the jobsite. The longest span crossing Monroe is 200 ft.

With both gantry and truck cranes, Danny's Construction erected the bridge, which never simply stands on the ground but rather sits on columns above a parking lot, a busway and train tracks as well as hanging onto the museum addition by two cantilevered beams. It took three to four months to plan the three-hour lift. Placement of the 110,000-lb section crossing Monroe St. required that the truck crane be located below Monroe on the busway.

The bridge rises to the level of art by leading to the Art Institute and by being a work of art itself. Since May, hundreds of thousands of people have walked up this structure.

Chicago Metal Rolled Products can curve plates 12 ft-wide and 2 in. thick.

Bridge sections being fabricated at Industrial Steel Construction.



Danny's Construction crane operated from a busway below Monroe St. and lifted the 110,000-lb section to cross it.

No visible weld seams.

While enjoying the views of the city, the park, the lake and especially the new addition to the Art Institute, **walk up the bridge**, enter the museum, proceed to the terrace and an overview of Millenneum Park.

Modern Wing of the Art Institute of Chicago:

The Light Fantastic

Photo by Charles G. Young

Photo by Charles G. Young

Photo by Dave Jordano

Photo by Dave Jordano

Above: Light, airy steel construction that appears to float.

Below: Art with a view of the park.

Above: A "flying carpet" to allow non-destructive natural lighting of art.

Below: Architect Renzo Piano at the jobsite.

In 1999, Renzo Piano was hired to design a 75,000-sq.-ft addition over the railroad tracks on the south campus of the Art Institute of Chicago. But with the explosion of activity at Millennium Park—the music pavilion, Cloud Gate, the BP Bridge, the Harris Theatre, etc.—and with the departure of the Goodman Theatre on the north side of the museum, in 2001 Piano ended up designing a 264,000-sq.-ft addition on the opposite side of the Art Institute providing more than three times the space of the original plan.

While designing the Modern Wing, Piano experimented with scale and proportion with his two Exelon Pavilions at the south end of the park facing the museum. These pavilions—each subtly different—represent mini-façades for his design of the museum addition and provide access to the parking garage below.

Renzo Piano's design is composed of glass, steel and limestone, which matches the stone of the existing museum. Most art museums do not have much glass because of the harmful effects of sunlight on precious art. Piano addressed that concern by hanging a "flying carpet" above skylights to filter light and eliminate the threat to the art. This sunshield supported by steel columns above the third floor is composed of extruded aluminum fins precisely angled to collect and redirect natural light from the north. Additional screening and computer-adjusted electrical lighting achieve the ideal combination of appropriate lighting, reduced electrical expenses, and art preservation.

While other architects might use heavier construction to make their structural statement, Piano's airy, lightweight design with meticulous attention to detail succeeds in his own way. Notice the extremely thin steel pipes tapered at the top and bottom with connections to support the "flying carpet." The glass roof of the top-floor galleries is further supported by delicate steel trusses. Piano is guided by a "zero-gravity" concept with details that suggest that everything is floating: a small reveal on the bottom of stationary and moveable walls, and on benches; the suspended staircases: and a complex double façade all contribute to the effect.

And the glass wall on the north end of the museum offers enticing views of the park and city that would otherwise be unavailable to the public. Construction System, Inc. fabricated the steel, Area Erectors erected the building, and Ove Arup & Partners were the engineers. The bridge, the park and the museum operate in a symbiotic relationship creating architecture that truly rises to the level of art and allows the exhibition of gallery art not previously seen because of space constraints.

You can proceed to the museum, take the escalators down to the street level and return to the park, but that would entail walking either to Michigan Avenue or to Columbus Drive and crossing a busy intersection. Unless you'd like to dine at and/or visit the museum, I suggest you **walk down the bridge** and proceed to your left to visit the **Burnham Pavilions**.

Burnham Pavilions:
Bold, Sustainable Forms

A bold marriage of steel and fabric in the complex geometry of Zaha Hadid Architects honors the bold plans for Chicago that Burnham made 100 years ago. The Pavilion can be disassembled and re-installed at another location following the Centennial celebration. A tensile fabric cover created by Fabric Images is supported by more than 7,000 pieces of aluminum, with no two alike, welded together to create the curved form.

Supported by a steel frame, the UNStudio pavilion, will be de-constructed and recycled when its exhibition is complete. Steel is the most recycled material in the world. Check out the interesting views of Chicago architecture as seen through the floating roof.

Exhibit panels adjacent to the pavilions explain the ideas and motivation behind the Burnham Plan Centennial. A touch screen allows visitors to make choices about our quality of life now and into the future by interacting with the Chicago Metropolitan Agency for Planning's (CMAP) regional GO TO 2040 plan.

If you haven't seen the Crown Fountain, you might want to walk a little south from the Burnham Pavilions to view it. (Isn't everything in this park wonderfully interactive?)

Photo by Michelle Litvin

Photo by Ben Dickmann

Photo by Joan Hackett

Above: Zaha Hadid of London deliberately expressed the aluminum frame through the fabric skin.

Left: The frame is composed of more than 7,000 different pieces of aluminum welded together.

Above: Ben van Berkel of Amsterdam designed UNStudio's curvilinear structure with its floating roof.

Right: Both pavilions can be recycled: steel is the most recycled material in the world.

Photo by Brian Willette

Walking along the back of the Jay Pritzker Pavilion, proceed to the east side of the park and the **BP Bridge**.

BP Bridge:
Curves Galore

Like the Pavilion, Gehry's bridge design—his first ever—went through at least ten iterations, at times to please the aesthetic tastes of Mayor Daley. The mayor was concerned that the bridge would draw attention away from the music pavilion. Even Gehry admitted his early designs looked "horrible." The final product serves both as a bridge and as a berm to muffle the ambient noise from busy Columbus Drive.

The long sinuous design allows for a gentle 5% incline while not taking up too much real estate connecting Millennium Park to Grant Park and the lake. Notice that there are no handrails, only side walls to protect pedestrians. The bridge is comprised of three different structural systems. Reinforced concrete walkways and piers on either side of the street anchor two cantilevered steel trusses incorporating 20-in.-diameter pipe with a 2-in. wall that is curved. The curving process was heat induction bending: after heating, a 2 in. length of pipe is mechanically bent, cooled and advanced to heat and bend the next 2 in.

Littel Steel did the fabrication, which was made easier when SOM provided all the center-line dimensions, measurements not always provided on a Gehry project. Connecting to the cantilevered trusses is the third element: a 6-ft-wide, 3½-ft-deep box girder with a curved underside. Supported by the cantilevered sections and a concrete center pylon in the middle of Columbus Drive, this member carries the load. Outriggers welded to the box girder cantilever widthwise to form secondary structures for the skirts on the bridge. The relatively thin bridge incorporates plate as thick as 1½ in. to achieve its aesthetically pleasing shape.

Gehry's signature style is again expressed in 9,406 stainless steel shingles fabricated by Permasteelisa Cladding Technologies and attached with 132 steel studs from Radius Track. This bridge also provides drop-dead views of the city, the parks, and the lake as well as a view of the struts that support the headdress above the Gehry pavilion. Imperial Construction Associates erected the bridge over Columbus Drive in a single weekend, with two welded air splices performed in the field.

Renzo Piano deliberately designed his bridge to be a direct counterpoint to that of his friend, Frank Gehry. Piano's bridge is 620 ft long and 60 ft high; Gehry's is 925 ft long and 14½ ft high. Piano's is a straight, sleek racing yacht; Gehry's a winding snake. Piano's is a steady incline only; Gehry's rises up and then returns to grade level. Piano's complements his Modern Wing; Gehry's his pavilion and trellis.

Both provide an exhilarating experience for any visitor.

Littel Steel completely preassembled the structural steel.

Imperial Construction Associates erected the sections over Columbus Drive in one weekend. Cladding was done by Permasteelisa and Radius Track.

Summary
and Millennium Park Map

Photo by City of Chicago, Peter J. Schulz

Donors, the City of Chicago, the Art Institute of Chicago, architects, engineers, structural steel fabricators, specialty subcontractors, and erectors—thousands of individuals—collaborated to meet the challenges of designing, fabricating and erecting these amazing steel structures. Teams created the structural underpinnings to support the loads above the garage, the railroad tracks, the busway and even a restaurant. Further complicating issues of weight, moving very heavy pieces required big machines which are heavy themselves.

A considerable amount of construction was completed not in a controlled, shop environment but in the middle of downtown Chicago with its busy pedestrian and vehicular traffic. And much of the work was done within a fully functioning park.

One example is typical of preparation and execution required to build the steel structures of Millennium Park: over 100 metal fabricators, cutters, welders, finishers, engineers, technicians, ironworkers, erectors and managers worked for five years to create Cloud Gate. In 110° heat, wearing protective suits and respirators, hanging from harnesses in a tent on the jobsite, skilled craftsman polished the mirror we lovingly call "The Bean." Those of us who enjoy this park owe a debt of gratitude to all who contributed.

From the BP Bridge, proceed to your final destination.
I hope you enjoyed the tour.

George Wendt
President
Chicago Metal Rolled Products

Millennium Park Map

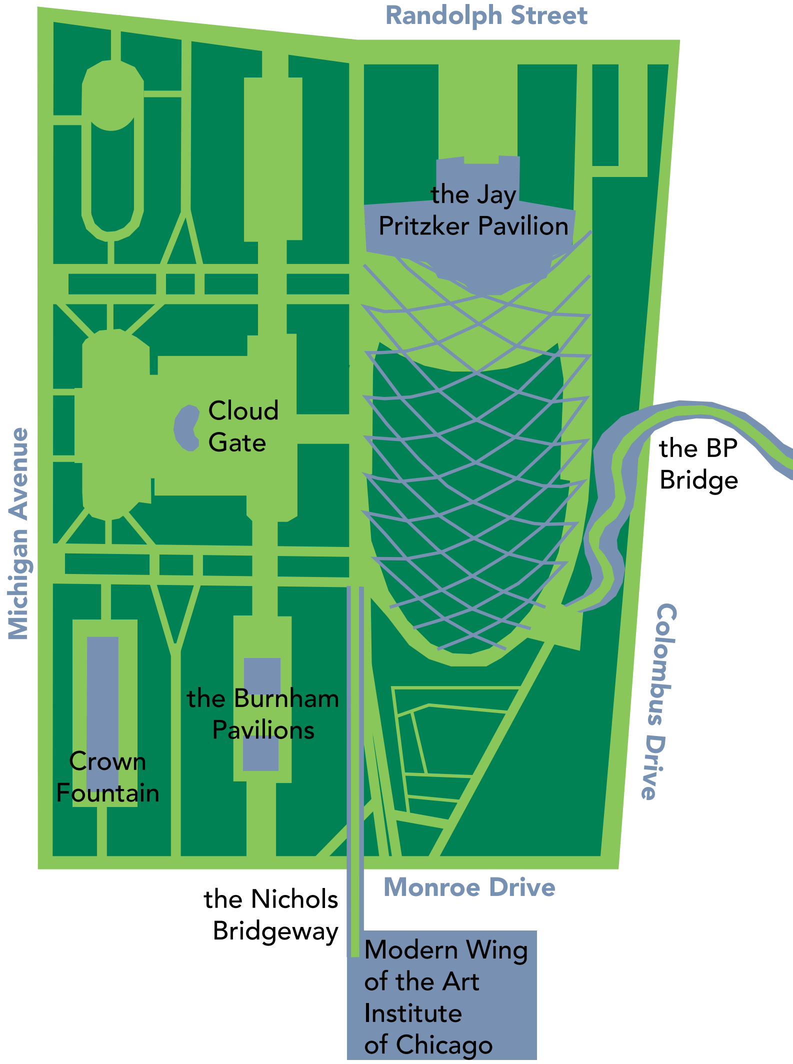


Photo by City of Chicago, Peter J. Schulz

Left: Millennium Park Site 1998

Opposite page: Opening Weekend 2004

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