Structural Engineering for Gehry's Curves at Millennium Park, Chicago, USA

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Summary

The Chicago skyline is known for its innovative architecture. Lakefront Millennium Park opened in the summer of 2004 amid widespread anticipation and interest from the general public and architectural enthusiasts. Designed by architect Frank O. Gehry, the Jay Pritzker Pavilion and great lawn provide seating for up to 11,000 people with a celebratory stage area framed by soaring, ribbon-like forms (the "metal elements"). A network of exposed arched steel members create a unique, three-dimensional open-air "trellis" high above the lawn and seating area that distributes sound throughout the entire lawn area, creating a truly modern acoustical environment. The serpentine BP Pedestrian Bridge across Columbus Drive linking Millennium Park to the lakefront represents Mr. Gehry's first realized bridge design.

Keywords: AESS, Trellis, BP Bridge, Metal Elements, Band Shell, Frank O. Gehry.

1. Pritzker Pavilion Bandshell

Figure 1: Millennium Park Project, Chicago

Figure 2: Band Shell Framing-Looking

The music pavilion is composed of a south-facing band shell housing the stage and related support facilities, which in turn supports the metallic forms. See Figure 1. The metal forms are shaped and located to improve the acoustic characteristics of the performance venue. The central portion of the band shell roof over the stage cantilevers up to 30 meters beyond the proscenium door. There are a total of 12 individual metal-clad assemblies arranged around and above the central stage, forming and overall composition about 100meters wide by 40meters tall. Behind the upper metal surfaces, a series of inclined steel pipe struts are connected to the band shell roof structure to support and stabilize the metal elements. See Figure 2. In front of and above the stage, the band shell roof framing consists of a three dimensional structural steel platform that consists of 12- built-up structural steel trusses spaced at 3 meters on centre and vary in depth from 3.4 meters, at the proscenium door, to 1.5 meters at the tip of the cantilever, where the majority of the metal elements are connected.

A steel grid frame concept was developed for the

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support of the metal elements, which responded well to the structural system requirements while closely following the curvature of the metal element shapes in order o take advantage of the inherent geometric stiffness of each form. The basic structural concept was applied and refined through computer based surface modelling that requires an integrated effort between the structural and architectural design teams.

2. Great Lawn Trellis

The Music Pavilion integrates the space and audio quality of an indoor performance theater with the openness and ambiance of an outdoor musical venue reminiscent of great band shell parks. A three dimensional shell-shaped trellis structure, formed by a grid of arched steel pipes, defines the audience space and connects the stage to the great lawn.

The trellis structure supports a system of computer controlled surround-sound audio speakers and a video system to create light and amibience effects. Hovering over the lawn, the speaker system, above and around the audience, eliminates the need for loudspeaker towers that is typically used at outdoor concert venues. The trellis shell encompasses an area approximately 300m x 100m in plan. The arched trellis frame is supported on 24-1.8meter diameter reinforced concrete pylons, 5 meters high and spaced 18 meters apart. Twelve arches originating from each side of the lawn span in an inclined direction, creating a distinctive skewed and gridded form. See Figure 3. The trellis structure behaves fundamentally as a discretized shell grid under gravity loads and resists the imposed loads primarily in axial compression. The imposed loads considered in the design included the suspended speakers systems, wind, ice, temperature, and maintenance live loads. Special analyses were performed to verify the overall stability of the structure under symmerical an assymetrical loading conditions.

Figure 3: View of the Trellis Structure and the Great Lawn

3. BP Bridge

The BP Pedestrian Bridge provides a pedestrian crossing over Columbus Drive between the park area above the East Monroe Underground Garage (construction circa late-1970's) to the newly built Millennium Park above the Millennium Park Garage to the west. The bridge is unique in that not only does it follow a complex curvature, but it includes a superimposed cladding system of stainless steel and secondary cladding support structure similar to an enclosed building. The approach spans to the east and west of the Columbus Drive span are curvilinear in plan and are framed in cast-in-situ reinforced concrete bearing walls and one-way slabs. The top of the bearing walls follow the slope of the bridge; generally sloping up from the beginning of the approach spans to the center of Columbus Drive. All longitudinal reinforced concrete bearing walls are supported directly by the existing underlying garage structures. See Figure 12. The two-span bridge over Columbus Drive is framed in structural steel supporting a cast-in-situ reinforced concrete walkway deck. The two-spans over Columbus Drive are on the order of 30meters each and are curved in plan. Limited the vibration of the bridge to 3Hz was one of the design criteria considered in the design. The bridge is supported on fixed bearing at the center and on horizontal expansion bearing at each end.

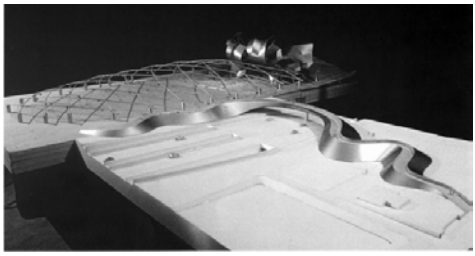

Figure 3: The Music Pavilion and the BP Bridge