Schubert Club Band Shell

St. Paul, MN

Photograph courtesy Brian Gulick.

Juror Comment

"Refined section analysis, perfectly detailed, well-considered. Innovative design approach for lateral and refined loads. Good use of advanced computer modeling. Very elegant"

Raspberry Island, on the Mississippi River near Saint Paul, MN, is now home to an innovative steel structure that has helped reincorporate the island into the surrounding urban fabric. The Schubert Club Band Shell features a glass-covered anticlastic stainless steel lattice that uses an innovative system of offset pipes and rod diagonals that proved more economical than a more common welded grid.

The Schubert Club sponsors performing arts and an annual concert series, and for several years the club sought an outdoor location for performances. The club chose Raspberry Island because of its location and proximity to downtown.

Seasonal flooding precluded the use of closed shapes and required a robust base to resist impact from flood-borne debris. The Schubert Club hoped for an architecturally significant structure that would establish the island as vital public gathering ground.

Structural System

The structure includes a 25′-0″-wide anticlastic lattice that spans 50′-0″ to precast concrete piers and covers a wood-framed stage. Acid-etched glass is offset from and supported by the lattice. The piers are attached to below-grade pile-supported footings connected by three grade beams. The beams resist the lateral thrust of the lattice and support the stage.

The lattice surface is formed by rotating an upward-curving arc generator through a downward-curving arc. Angled planes form a quad-symmetric saddle shape. The abutments are tangent to the ends of the lattice and shaped as tapered extrusions of the arc generator. The lattice geometry allows repetition in glass sizes and detailing. It also allows all glass panels to be planer, avoiding the use of triangular or warped pieces of glass.

The lattice is made up of two layers of 1-7/8″-diameter pipes in opposing directions and a middle layer of 5/16″-diameter rod diagonals. The top-layer pipes are spaced at 2′-0″ and span to the piers. These pipes are load-carrying elements and act as a series of joined arches. The bottom-layer pipes are spaced at 2′-6″ and span to the edge beams. Due to their high level of curvature, they act as secondary arches bracing the pipes in the top layer. Pipes in both layers have varying wall thickness: 3/16″ in areas of low stress and 3/8″ in areas of high stress.

The two layers are joined at crossings with 2″-by-1-3/8″-diameter posts. The posts are welded to the top-layer pipes

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Structural Engineering Software
S-Frame version 5

and connected to the bottom-layer pipes by ½″-diameter through bolts concealed by the posts. A ¾″-long offset piece is welded to the top-layer pipes at each crossing. Each piece conceals the head of a through-bolt and is a base for a glass patch plate connection. The diagonals are 110 ksi stainless steel rods joined to machined split rings that fit around the posts. The diagonals are arranged so four diagonals form an X over four structural panels.

The lattice elements are connected to each pier by a continuous, curved, ½″-thick stainless steel plate. The plates were supplied to the precaster by the lattice fabricator to allow the lattice fabricator to control the positions of the connections relative to one another. Placing an embedment for each connection could have led to misaligned elements.

Structural Analysis

A shell formed by a continuous surface resists loads by in-plane shear and axial forces and low magnitude out-of-plane bending. The bandshell's lattice resists loads in a similar manner. Pipes develop in-plane axial and out-of-plane bending forces. Pipes and diagonals acting together resist shear.

The structure exhibits geometric non-linear behavior: loads magnify displacements and material non-linear behavior because the stainless steel is characterized by a non-linear stress-strain relationship. The analysis also included an evaluation of the structure's susceptibility to multi-panel buckling.

The structure was designed to limit-state theory. An elastoplastic variable secant modulus method was used to model material behavior. For a particular stress range, there was an associated secant modulus. With this method, high-stress regions were softened such that geometric stiffness was reduced and loads were redistributed. The method is similar to the one used to model the behavior of a variably cracked reinforced-concrete structure.

A non-linear iterative analysis method helped evaluate the structure. Combinations of snow loads and temperature differentials produced maximum stresses and buckling load ratios. Uniform snow loads were 40 psf; drifting snow loads approached 60 psf. Temperature differentials were considered for a 90-degree F range. The lowest buckling-load ratio for service loads was determined to be approximately 4. The maximum calculated deflection under service loads was 1½″.★