Steel serves as the star attraction as well as the background of an angular performance pavilion at the site of a former Pennsylvania steelworks.

All the World's a Stage

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MEMORABLE OUTDOOR CONCERT VENUES are often known for their dramatic backdrop.

Red Rocks Amphitheatre in Colorado is tucked into the foothills of the Rockies and surrounded by natural rock formations, with a view of downtown Denver. Alpine Valley in Wisconsin is nestled in a verdant landscape at the base of a ski slope. And the Levitt Pavilion SteelStacks in Pennsylvania sits directly in front of five hulking, 20-story blast furnaces.

While stone and wood define the first two venues, Levitt Pavilion is all about steel. The venue is a signature element of SteelStacks, an arts and cultural campus located at the site of the former Bethlehem Steel plant in Bethlehem, Pa. (see "Cool Centerpiece" in the "What's Cool in Steel" feature in our 08/12 issue for another SteelStacks project). Due to its surroundings, the exposed, cantilevered steel structure could not be a traditional band shell; the Bethlehem Redevelopment Authority requested that the design of the pavilion reflect the history and the aspirations of the people of Bethlehem. In the end, the design by architect Wallace Roberts and Todd, LLC (WRT) is a form that neither blends with the historical steel plant nor visually competes with it. Conceived as a large-scale, origami-like sculpture, it suggests a work still in progress.

The stainless steel panels form the shell of the Pavilion, creating an asymmetrical segmented arch.

Simpson Gumpertz and Heger, Inc.

The perforated stainless steel panels combined to form one of the 12 larger faceted panels

Simpson Gumpertz and Heger, Inc.

➤ Detail of the main framing rib at the cantilever end.

Far from Symmetrical

The pavilion's shape is a complex asymmetrical segmented arched shell that rises 37 ft from the ground and cantilevers 35 ft forward to shelter the stage. The shell then twists forward, folding stage left, back to the ground. The shell is formed from 12 large panels, each oriented with a differing angle to reflect light in a unique way. The 12 large faceted sections are clad with 3-ft by 6-ft 11-ga rectangular perforated 316L stainless steel plates.

WRT developed the conceptual shape of the segmented shell, and Simpson Gumpertz and Heger, Inc. (SGH) designed the primary and secondary structure from an evolving structural and architectural external geometry. The primary steel framing consists of six segmented structural steel ribs interconnected by smaller framing members. The lowest segment of the ribs is hidden from view by acoustical panels. These are 24-in.-deep wide-flange sections anchored to a reinforced concrete mat foundation. The upper rib segments are exposed to view and are comprised of 26-in.- or 28-in.-deep rectangular hollow structural sections. The HSS segments at the cantilevered end of each rib taper to a depth of 13 in. to provide a thinner appearance at the free edge. Before specifying them in the design, SGH (using contact information at www.aisc.org/availability) contacted steel plants to confirm that the sections would be available within the construction schedule. To ensure structural and acoustical performance, SGH designed for varying member depths and HSS wall thicknesses to maintain the uniform deflection at the front, free edge. Each rib section was approximately 75 ft long and was mitered at least three times. Although no rib was ever completely in a vertical plane, each rib was planar to reduce fabrication complexity.

The support of the perforated stainless steel cladding panels was an ongoing debate during the early design stages. Conventional enclosure construction suggested metal panels supported on Z-shaped steel sections fastened to the acoustical steel deck. However, the faceted geometries resulted in complex angles and shapes that indicated potential inefficiencies and related water drainage problems. The inefficiencies led to a decision to discard the conventional approach and design a system of secondary structural steel framing that posts up from the primary framing. This secondary framing system is composed of repetitively sized HSS6×6 or HSS6×4 and 2L3×3 double-angles that support the 3-ft by 6-ft stainless steel sections above.

Blending Functionality with Aesthetics

Despite the Levitt Pavilion's complex design, it exhibits many practical characteristics. For example, the structure's folded geometry, wrapping to the ground, screens the loading dock and the trucks that service it.

Rigging supports are welded to the bottom flange of the primary framing ribs. They are built from 7-in. or 12-in. deep inverted WT sections with end plates behaving as stoppers. Rigging clamps grasp the WT flanges to support rigging trusses with attached lighting, speakers and other equipment. Each rigging support location and load capacity of 1,000 lb or 2,000 lb was coordinated to allow for a range of rigging options.

EPIC ER3.5A 20 ga steel deck is placed between the primary ribs directly above the stage. The top of the steel deck aligns with the top of the primary ribs. Each deck section behaves as a simple span and is supported at the side faces of the primary ribs by welded 5/16-in.-thick by 4-in.-wide steel plates. The steel deck supports a layer of waterproofing that keeps the stage dry during sudden rain events.

Schedule Overhaul

The Levitt Pavilion was originally scheduled to open with only the concrete main stage in July 2011 and a completed pavilion in July 2012. However, the project team refused to settle for an unfinished product at the ribbon-cutting ceremony for the 2011 season. Therefore, a meeting was held between the design and construction teams to determine how

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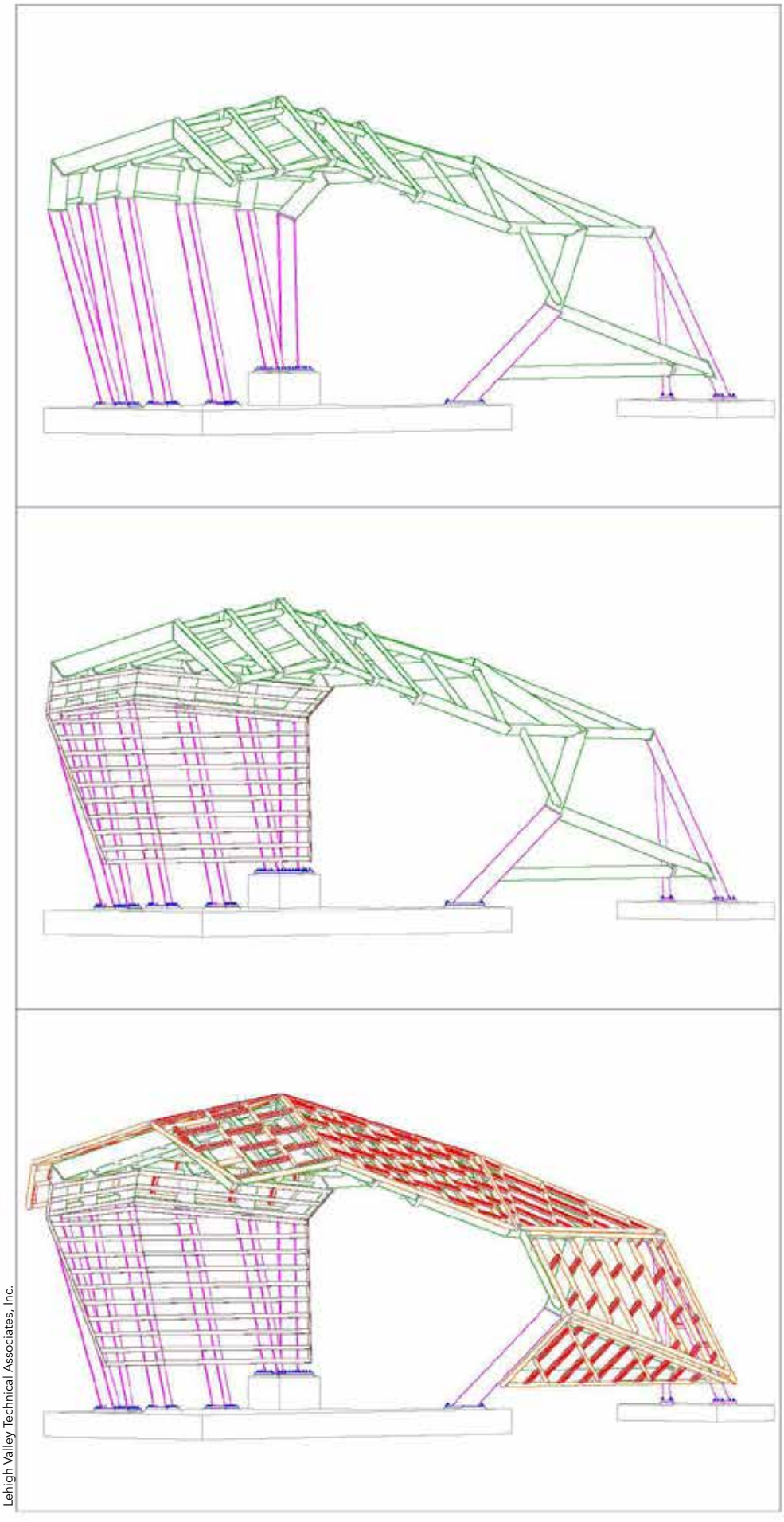

Lehigh Valley Technical Associates, Inc.

◄ Detailing model illustrating framing progression (main structure, main structure with acoustical panel support and completed structure).

to reduce the construction schedule by nearly one year. To achieve this rather lofty goal, the team identified and implemented significant time-saving measures, including design/fabrication model sharing, maximizing connection repetition, increasing the number of shop assemblies and streamlining the traditional shop-drawing review process.

The design team supplied the detailer and connection engineer, Lehigh Valley Technical Associates, Inc. (LVTA), and the steel fabricator, Levan Associates, Inc., with the 3D design model to transfer directly to the LVTA's software. The file transfer eliminated the time associated with recreating the complicated geometry of the structure. After minor modeling corrections due to geometrical limitations of the design/drafting BIM software were completed, all steel member sizes and orientations matched in the analytical and detailing models. In addition to the reference model, the design team provided the detailer with 2D architectural drawings to understand the overall design concept and 2D structural drawings indicating member sizes, complex connection geometries and typical connection details for various geometries.

With the detailing model in progress, LVTA and Levan focused their attention on the connections of the structure. Most connections are skewed, sloped and canted, increasing their complexity. To facilitate simpler steel fabrication and erection, the firms proposed several slight geometrical changes to the primary framing to achieve a more regular alignment with the secondary framing. These changes provided repetitive connections, saving modeling, detailing and fabrication time. All proposed geometrical changes were reviewed via interactive web meetings with the Philadelphia-, Bethlehem- and Boston-based teams. Most changes were accepted and integrated into the structural, architectural and fabrication models nearly immediately.

LVTA coordinated the connection types with Levan's fabrication capabilities, providing as many shop assemblies as possible. LVTA proposed modifying the connections between the primary rib segments from full-penetration welds to fillet welds to increase construction efficiency. Additionally, Levan and LVTA proposed that most other connections change to fully field-welded from the envisioned bolted connections. Because the connections transferred shear, axial and bending forces, the fully welded detail required less fabrication and additional erection welding, providing a cleaner visual appearance. A hidden erection aide and an alignment hole were the only shop fabrication details needed. The additional rigidity in the connections necessitated reanalysis of the overall structural framing to fully understand the implications of the welded connections. SGH updated the structural 3D analytical model for the connection changes and provided updated forces for the final connection design by Levan and LVTA. These updates greatly improved shop and field schedules, and the structure was erected without any major field fit-up issues.

The final major effort was to simplify the review process. The time required for the traditional shop drawing review procedures was simply not an option and was replaced with open communication and collaboration, typically around an online meeting platform. Because of the inherent design-build nature of the project during the detailing phase, the design team made many of the connection decisions as detailing progressed. By the time the shop drawing review process began, all design changes had already been reviewed and accepted. This allowed for an expedited shop drawing review and an early fabrication start.

Erection of the primary ribs, with shoring provided by temporary wide-flange columns.

Way Ahead

Levitt Pavilion SteelStacks was completed well ahead of schedule and in time for the season's first performance on July 2, 2011, using 81 tons of structural steel. The total design phase took less than six months and the construction schedule less than five months. The pavilion is a sign of the ongoing revitalization and reintegration of the 1,600-acre Bethlehem Steel plant into the surrounding community. What was once the second-largest steel producer in the United States now serves as a backdrop for community development through art and music. The pavilion is not only a tribute to the steel industry of the past, but also an inspiration for the steel industry of the future. MSC

The structure is a system of large support ribs, infill framing and secondary framing for exterior panels.

Lehigh Valley Technical Associates, Inc.

▲ The primary structure is erected above the stage, the shoring is removed and the EPIC steel deck installation is underway.

Owner
The Bethlehem Redevelopment Authority, Bethlehem, Pa.

Architect
Wallace Roberts and Todd, LLC, Philadelphia

Structural Engineer
Simpson Gumpertz and Heger, Inc., Waltham, Mass.

Construction Manager
Boyle Construction Inc., Allentown, Pa.

General Contractor
Bracy Contracting, Inc., Allentown

Steel Team

Fabricator
Levan Associates, Inc., Emmaus, Pa. (AISC Member/ AISC Certified Fabricator)

Detailer and Connection Engineer
Lehigh Valley Technical Associates, Inc., Northampton, Pa. (AISC Member)