"An example of **structural steel** that is able to go from brute strength to amazing grace in a single building."
—Andy Johnson

All photos in this spread by Timothy Hursley.

Presidential Award of Excellence in Engineering and Architecture

KAUFFMAN CENTER FOR THE PERFORMING ARTS KANSAS CITY, MO.

The 400,000-sq.-ft Kauffman Center for the Performing Arts was designed to create a focal point for Kansas City's burgeoning arts district. And with a 1,600-seat concert hall, 1,800-seat ballet/opera house, café, garden and underground parking garage, it certainly commands attention.

Actually three buildings in one, the Kauffman Center required different structural approaches for different areas. In the two performance halls, for example, key issues included the need to create wide, column-free spaces and support the sound-reflecting concrete ceilings. Structural engineer Arup's solution included straight, long-span steel trusses (90 ft in the opera house and 115 ft in the concert hall) tapered in depth to provide greater strength where needed.

For the exterior shell, the geometrical complexity of the architectural design presented a very different challenge. For the unique toroidal roof, Arup devised an efficient truss system made of single-direction rolled steel. The design is based on roof trusses curved out of plane by rolling the truss chords to produce the toroidal shape. The trusses are laterally braced from rotation by the intermediate radial roof members (curved the hard way) and the constant tension imposed by the southern cable net. The multifaceted curved-back surface is also made of curved trusses, but this time curved in-plane. The various facets look different, but are actually identical rolled sections made to look unique by varying the center point of a constant radius.

When it came to the atrium, an exterior pre-stressed stainless steel cable net was used to support the roof and walls, thus avoiding the need for interior columns and beams, to achieve the desired spacious, open quality in the glass-roofed lobby. Splaying the external cables allowed lateral bracing to be omitted, as well as facilitated the use of clear, open glazed walls.

The structure's cable-net roof presented a number of unique opportunities for advanced collaborative engineering. Cables typically perform poorly in fires, and consequently require costly, bulky fireproofing sleeves. The fire and structural engineers worked together to eliminate the need to encase the cabling. For instance, for the passenger drop-off point, digital models demonstrated that substituting high-strength rods for cables on the building's exterior would permit the elimination of fireproofing (because mechanical connections have higher heat resistance, the rods dissipate the heat gained by the fire).

For the interior, Arup modeled the fire-induced release of several cables in a fire scenario, proving that those cables within the flames' reach were not critical to the vertical support of the glass. For the vertical column masts, which are critical to atrium support, intumescent paint treatments were used to keep profiles as slim as possible.

The architectural design features steel on the building's north-south-facing sides, which are curved, and concrete on the east-west-facing sides, which are flat. In the lobby, exposed stainless steel masts, cables and a truss spanning both walls combine with the massive glass walls to create a dramatic setting for events and gatherings. In the concert hall, stainless steel mesh forms the backdrop for the stage.

Modeling and analysis were particularly important to a structure with such an unusual shape, as was early integration and sharing of these models with specialty contractors. Sharing the stiffness results of the structural model with the cable




supplier and general contractor allowed the cable supplier to bracket anticipated structure movement and check glass deflection and warping. Likewise, the contractor shared the cable stressing and construction sequence with the design team. This allowed the design team to check the frame performance over the sequential stressing operation.

For the cables supporting the glass lobby structure, nonlinear analysis and form-finding were used to balance the effects of gravity, wind and other conditions and determine the most structurally efficient shape.

Of course, being a performance venue, acoustical considerations were of the utmost importance. To provide the best possible sound in the two performance halls, a "box-in-box" approach was employed. The dense concrete walls of the two performance spaces provide acoustical benefits. The halls are covered by long-span steel trusses supporting two separate layers of sound-reflecting concrete caps. These two buildings are then covered again by an external steel-trussed shell and glass roof. In the finished building, the outer steel shell roof helps block vibration and noise from the surrounding city, while the glass roof provides a circulation link between the halls.

In addition to acoustical benefits, the split in materials saved time and money and the construction schedule was shortened by several months. While the detailed design, approval and fabrication for the steel portions were underway, concrete was formed, cast and allowed to cure. As soon as steel fabrication was complete and the parts transported to the site, the rest of the building was assembled relatively quickly. MSC

Owner/Developer
Kauffman Foundation/Land Capital Corp., Kansas City, Mo.

Architects
Safdie Architects, Somerville, Mass.
BNIM Architects, Kansas City, Mo.

Structural Engineers
Arup, New York
Structural Engineering Associates, Kansas City, Mo.

General Contractor
J.E. Dunn Construction, Kansas City, Mo.

Steel Team

Steel Fabricator
Hirschfeld Industries, San Angelo, Texas (AISC Member/NSBA Member/AISC Certified Fabricator)

Connection Designer
Structural Solutions, Inc., Fort Worth, Texas (AISC Member)

Steel Erector
Midwest Steel, Detroit, Mich. (AISC member)