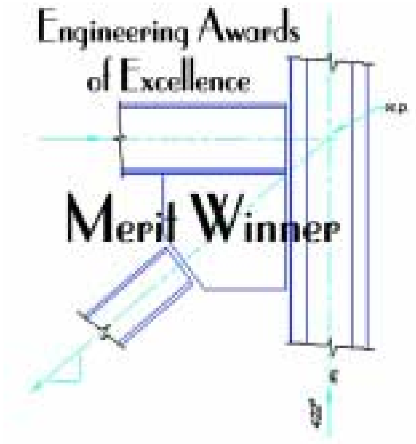


Nancy Lee and Perry R. Bass Performance Hall

Fort Worth, Texas

The Fort Worth cultural district is the third largest arts district in the nation. Acknowledged as one of the finest museum districts in the world, Fort Worth houses an elaborate collection of artwork in the internationally known Kimbell Art Museum, the Modern Art Museum of Fort Worth, the Fort Worth Museum of Science and History, and the Amon Carter Museum. At the same time, five world-famous performing arts organizations – the Fort Worth Symphony Orchestra, Fort Worth Dallas Ballet, Fort Worth Opera, Van Cliburn International Piano Competition and Concerts, and the Casa Manana Theater – also reside in Fort Worth. What the city lacked, however, was a first-rate performance hall – a home – for these organizations.

The future of the performing arts in Fort Worth had long been a concern for area leaders. Conditions were so dire that the orchestra rehearsed at one facility and then traveled to another to perform. In 1992, Performing Arts Fort Worth, Inc. (PAFW) was formed to manage the design, construction and operation of a world-class multi-use performance hall in Fort Worth. PAFW hoped to build one facility that would meet the needs of each of the resident performing arts organizations and successfully host various traveling performances. PAFW established four goals for the performance hall: to provide a home for the major performing arts organizations of Fort Worth, to provide a world-class venue for touring artists and attractions, to serve as a catalyst in the economic revitalization of downtown Fort Worth, and to be a driving force in the integration of the performing arts into the curriculum of the public schools.

PAFW retained David M. Schwarz/Architectural Services to design a performance hall that would meet each of these goals. The firm has built a strong reputation in the Dallas/Fort Worth community based on a variety of distinctive projects, including the Ballpark in Arlington; Cook-Fort Worth Children's Medical Center, and the mixed-use Sundance West apartment/entertainment complex in Fort Worth. The design-oriented firm believes that a healthy respect for the past is a key to understanding the present and helps define directions for the future. Schwarz's goal for Fort Worth's performance hall was to design a state-of-the-art, multi-use facility by returning to traditional design and planning concepts which have not been used for performing arts centers in decades.

Jurors' Comments

"The designers utilized several Innovative solutions, such as the use of a torsion tube, to a very complex design problem. "

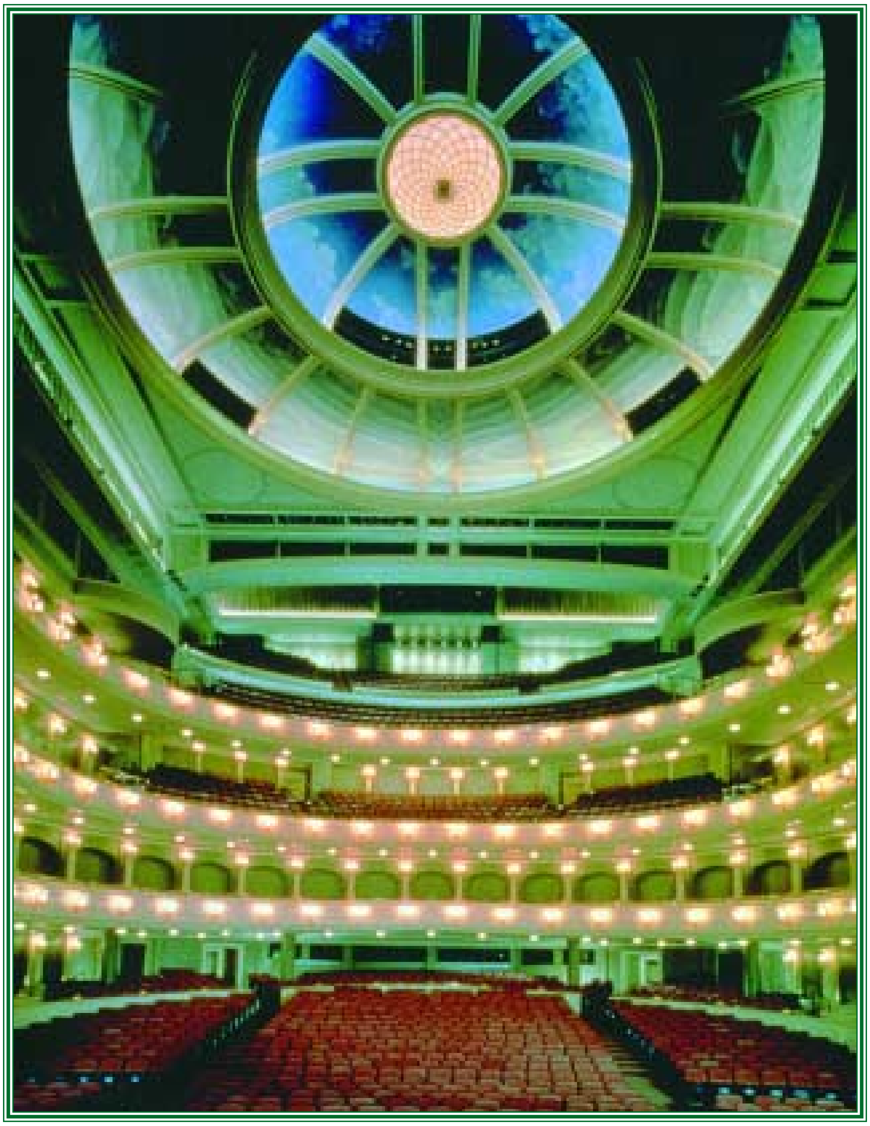
"The use of 3'x3' box girders to provide unobstructed views along the horseshoe-shaped seating was an outstanding design concept."

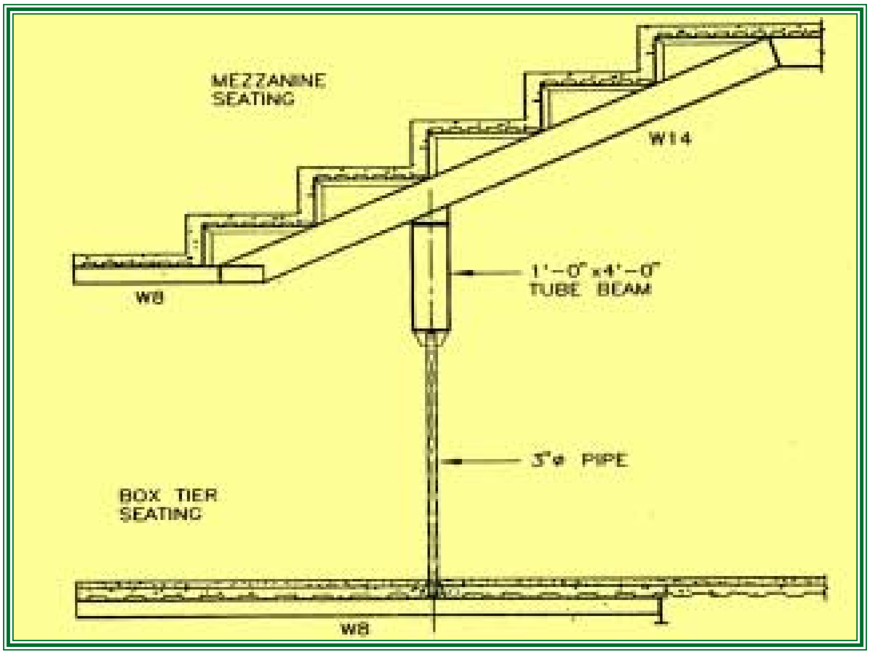
"The vibration analysis and design considerations to meet the building's acoustic needs were impressive."

The goals of both the owner and architect were met with the Nancy Lee and Perry R. Bass Performance Hall, a 2,056-seat multi-use performance theater located in Fort Worth's downtown Sundance Square. Opened in May 1998, the $65 million Bass Hall was funded by private donations contributed by individuals, corporations, and foundations. Bass Hall has been described by the Toronto Star as "one of the great concert halls of this century." The structural engineer's use of structural steel as the primary construction material is a key to the project's success.

Owner's Program

Walter P. Moore and Associates, Inc., the structural engineering firm on the project, utilized a variety of engineering skills to design the world-class performance hall. In spite of the





complex design challenges presented by the traditional 19th century opera house seating design, the project was completed within budget and in accordance with the owner's schedule requirements.

Steel Framing System

The first crucial engineering decision was the selection of an appropriate material for construction. Engineers compared cast-in-place concrete versus structural steel systems and performed various analysis of both systems. Although cast-in-place concrete offered some advantages, steel offered two primary strengths. First, steel framing eliminated the need for geometrically complex and expensive concrete formwork. The hall required more than 84,000 pieces of steel, an unusually high number that reflects the intricate complexity of the performance hall. Second, designing with steel allowed engineers to resolve any complications in the draft stage rather than in the field, which could have delayed the relatively fast moving, four-year project.

Careful engineering and collaboration assured that a steel frame supported the desired acoustically pure environment just as efficiently as a cast-in-place concrete frame. Working with the acoustician to ensure that the structural frame would minimize vibrations and noise generated by the audience, the engineers carefully analyzed the structural frame, focusing particularly on the seating cantilevers. Additional mass in the walls, floors and ceiling, as well as careful jointing throughout the structure, was specified to help maintain the sound environment.

Structural roof framing

Acoustical considerations also played a major role in the design of the structural roof framing. The thick plaster ceiling used to isolate the audience chamber acoustically required more structural support than conventional ceiling construction. Engineers developed structural roof framing that used a series of 12'-deep trusses spaced at approximately 40' on center. The framing spans the 92' width of the audience chamber within the available vertical plenum space. The basic roof construction consists of conventional metal deck on steel beams, but the acoustician required special provisions to create an adequate sound barrier: a 48" air space below the roof, enclosed by a 100 psf slab. This mass was achieved with a 9½"-thick slab consisting of 6 ½" of normal-weight concrete on a 3" metal deck. A level of composite steel beams located within the depth of the main roof trusses supports this slab.

Ductwork was placed immediately below the acoustical roof slab, within the remaining depth of the roof trusses. Because the ducts for incoming air supply took up all the available space in the ceiling plenum chamber, engineers routed the return air from the audience chamber through tunnels beneath the lowest seating level and into the mechanical rooms.

The ductwork also prevented ceiling and catwalk hangers from reaching the acoustical slab framing, so we added another level of framing at the roof truss bottom chord elevation. This framing consists only of a grid of beams, arranged in plan to support hangers from suspended catwalks and plaster ceilings below.

Rigging System

The design called for an extensive counterweight rigging system for the curtains, scenery, lighting and other staging components that the hall uses to accommodate various stage shows. Operators can deploy a secondary, movable ceiling to achieve the appropriate acoustical environment in the audience chamber. To accomplish this, our engineers specified a system of rigging lines spaced at 6" centers over the full depth of the stage. The rigging loads are suspended from pulleys attached to steel roof beams that are spaced across the stage width. The pulleys direct the rigging lines horizontally to another large series of pulleys at one end of the stage. These master pulleys are supported by headblock steel beams, which span 60', unsupported, from the front to the rear of the stage. The rigging lines then turn down at the headblock beams to the counterweight zone.

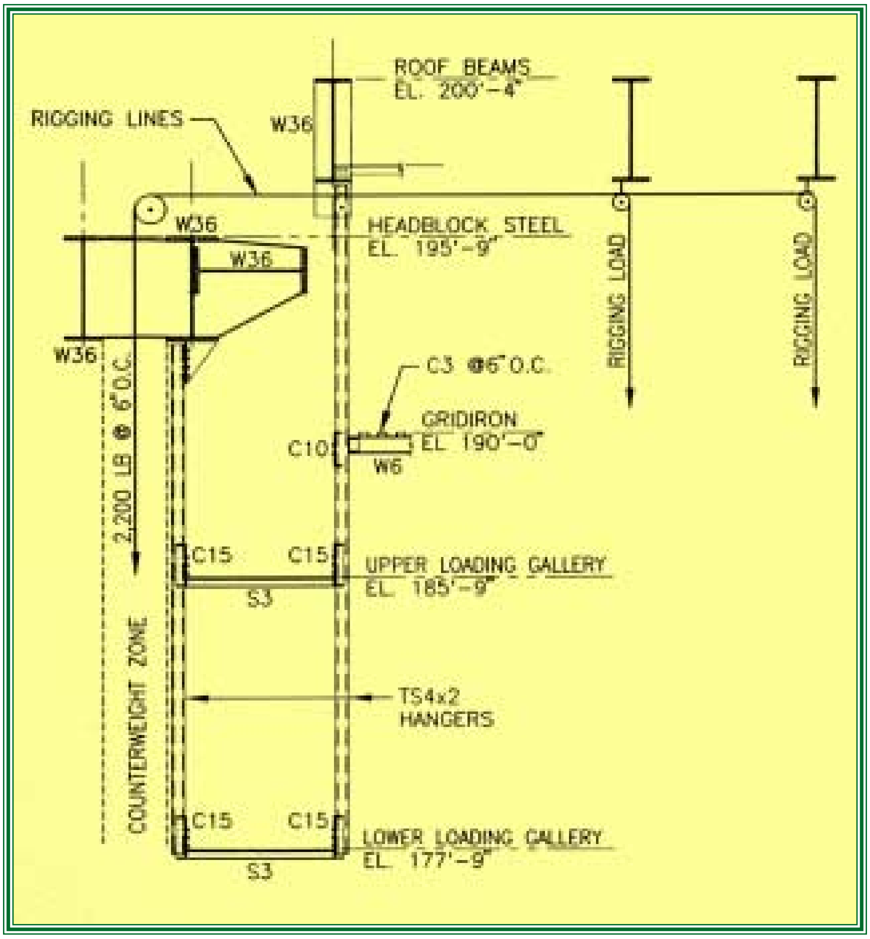
Operators can add counterweights from upper and lower loading galleries as required to support the rigging loads. The loading generated by the turned rigging lines is significant - 2,200 pounds at 6" centers both horizontally and vertically. Heavy, W36 sections welded into a single headblock beam resist these design loadings.

Structural Efficiency

The steel structural system proved to be highly efficient. During schematic design, the engineer estimated the weight of the structural frame at 1800 tons; the final tonnage was 1805 tons, a minuscule .28 percent over the initial estimate. As a result, cost "creep" from schematic design to construction was eliminated and the budget was achieved. Creativity, thoroughness and accuracy of structural documentation allowed the structural frame to be completed on schedule and within budget. The frame was topped out only ten months after the start of construction, and structural change orders amounted to less than one percent of the frame cost. The steel framing system also offered solutions for the challenges presented by the horseshoe seating design.

Innovative Technology

The success of public assembly facilities greatly depends on the seating design, which is complex because of the various seating levels and the demand for unobstructed sight lines. Designed with a classic horseshoe shape in the style of a 19th century opera house, the audience chamber of Bass Hall provides five levels. Each of the five seating levels presented a different set of structural concerns. The second level (box tier) demanded the most creativity. The intimate box tier level features seating boxes that measure 8' by 10', each with a private entry from an anteroom off the main public corridor. Because the box tier level cantilevers over the orchestra level, engineers could not use supporting columns that would have obstructed the views of those in the orchestra level below. The horseshoe configuration also complicated the framing, limiting structural depths to eight inches if those seated below were to have unobstructed sight lines. The design team elected to frame the box tier level using a shallow and economical system of 8" deep, wide-flange steel beams. This system hangs from the mezzanine level above using 3" diameter pipe hangers, effectively eliminating all concerns about columns that might block the view. Of course, this moved much of the structural challenge to the mezzanine level above, demanding an innovative engineering answer. To position the seats for that level properly, the three lowest rows of the mezzanine level cantilever approximately 10'. Although the structural depth was not overly restricted, architectural considerations dictated that only two columns be used in the box tier back wall, severely restricting choices for support locations for the mezzanine above. The engineer designed a deep, curved steel tube beam to span between two columns hidden in the box tier back wall, at the rear of the parterre seating area below. Fabricated from A572 grade 50 steel plate, the 12" by 48" tube gracefully curves between the columns, following the geometry of the seating horseshoe. The



mezzanine level cantilevers directly over the top of the tube to create the desired vertical seating alignment without compromising the view from below.

The second level seating design demanded engineering creativity and prepared engineers for an even greater structural framing challenge: the upper and lower gallery seating levels.

The challenge of the upper and lower gallery seating levels was met with an innovative solution. Due to architectural constraints, the lower portion of the balcony seating, which cantilevers over the mezzanine seating, could not have a back span. The structural engineer developed a unique torque-tube concept to allow the structural framing to work within the architectural constraints.

At the lower gallery, the seating rows were intended to cantilever well into the main audience chamber, which is common for a performance center. However, at this level, the back span depth was limited to 8" by the ceiling heights in the public lobby behind and below the upper gallery. Since that wasn't enough to provide a conventional cantilevered solution, a torsionally stiff support beam offered the best answer.

Engineers designed a square beam with 36" sides to support the cantilevered loads in pure torque. Referred to as a torque tube, it curves to follow the horseshoe seating geometry, much like the tube beam at the mezzanine level below. Engineers specified A572 grade 50 plate for the tube. Two pairs of columns located at the back of the mezzanine seating resist the torsion accumulated in the torque tube. As if the lower gallery hadn't produced enough structural challenges, these column pairs had to be transferred out at the mezzanine level to accommodate a public lobby below.

For more information on this project, please see the article "Steel Horseshoe" in the December issue of Modern Steel Construction.

Project Team

Owner:
Performing Arts Fort Worth

Structural Engineer:
Walter P. Moore and Associates, Inc., Irving, TX

Architect:
David M. Schwarz/ Architectural Services

General Contractor:
Linbeck Construction Co., Fort Worth, TX

Steel Fabricator:
Steel Service Corp., Jackson, MS