# STEEL HORSESHOE

## The theater's extremely complexe geometry made steel the more logical choice

**By David A. Platten, P.E., and John A. Gregg, P.E.**

REFLECTING THE TRADITIONAL "HORSESHOE" DESIGN OF CLASSIC OPERA HOUSES, THE new Nancy Lee and Perry R. Bass Performance Hall, this worthy addition to a growing arts presence in Fort Worth is the home of the Fort Worth Opera, Fort Worth symphony Orchestra Association, Fort Worth Ballet, Van Cliburn Foundation and the Casa Manana Theater.

Designed by David M. Schwartz/Architectural Services Inc. and HKS Inc., it offers more than 2,000 seats on a surprisingly tight site.

Located on a 200'-square urban block, the performance hall's seats are arranged in a horseshoe formation with four tiers. It was that combination of the complex seating arrangement and tight site that led the designer's to a steel structure. Originally, it was expected that concrete—in large part due to its inherent acoustical advantage—would be a more cost effective framing system. However, a comparison of steel and concrete during the schematic design phase of the project revealed otherwise. The extremely complex structural geometry of slopes, curves, steps and column transfers would necessitate extremely complex formwork. It was felt that such unique forming requirements would eliminate a number of prospective subcontractors, thereby reducing competition and increasing costs on bid day.

Also, the tight site—in combination with the complex geometry—necessitated that the contractor do a great deal of up-front planning and coordination. With a structural steel frame, detailed shop drawing preparation would uncover any geometric inconsistencies, which could be addressed early on—on paper—rather than later in the field.

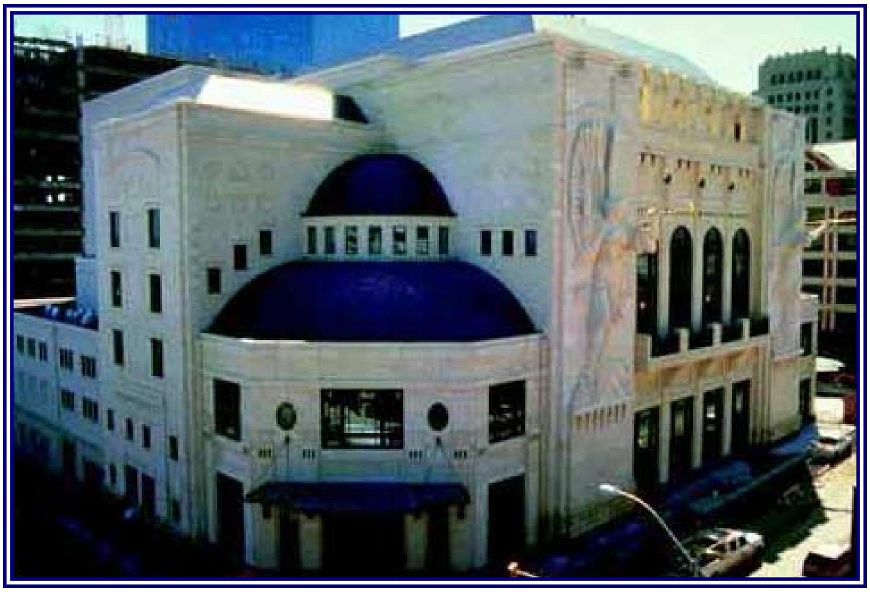
Before steel was chosen, however, the project structural engineers from Walter P. Moore & Associates, Inc., carefully analyzed the structural frame—particularly the seating cantilevers—to make sure that vibration levels would be in the acceptable range. Close coordination with the project's acoustician—Jaffe Holden Scarbrough of Norwalk, CT—helped to ensure that noise or vibration would not adversely affect the hall's audience. As part of this effort, extra mass was added to the walls, floors and ceiling throughout the structure and 2" silicone joints were used to separate the building's mechanical room from its basement.

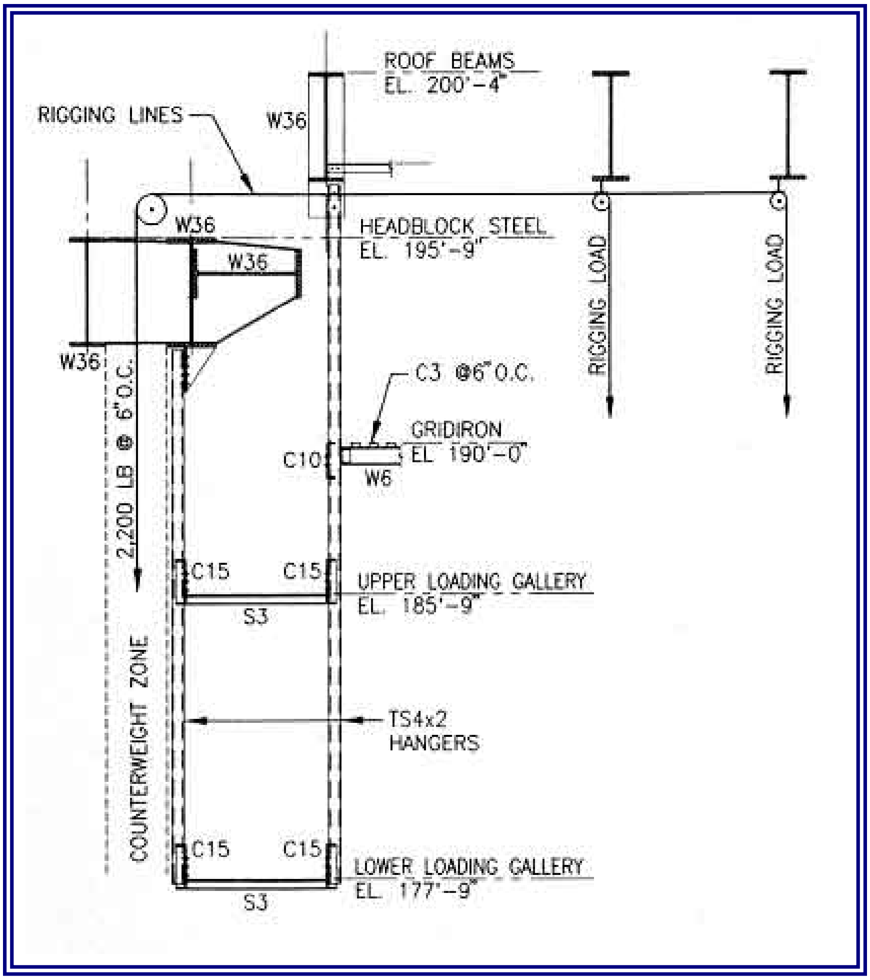
As with any concert hall, noise is a concern. One step was to locate the hall's central mechanical plant across the street and connect it via a tunnel to the mechanical room adjacent to the building's basement. In addition to reducing noise, this arrangement also allowed the construction of more seats than otherwise would have been possible. Also, a low air velocity venting system was designed, with air velocities of between 250 to 300' per minute versus the standard 600 to 700' per minute in most commercial buildings. Supply air was routed in the ceiling plenum, but because the slow air speed meant huge ducts, there was no room in the ceiling for return air. Instead, the return air was routed from the audience chamber to the mechanical rooms through tunnels excavated below the lower level.

Outside noise, especially in an urban setting, also is a major concern. Acoustic isolation was obtained by utilizing a "box within a box" design. The seating chamber was isolated from the lobby and support areas with a series of plaster-coated 8" and 12" concrete block walls and every seating level is separated from the lobby and support areas by an anteroom or hallway finished in sound-absorptive acoustic fiberglass.

### Lower Level Design

For a majority of the building, the single basement excavation reached the bearing strata,






*The diagra above shows the configuration and relationship of stagehouse rigging components. The gridiron serves as a work platform 90' above the stage.*

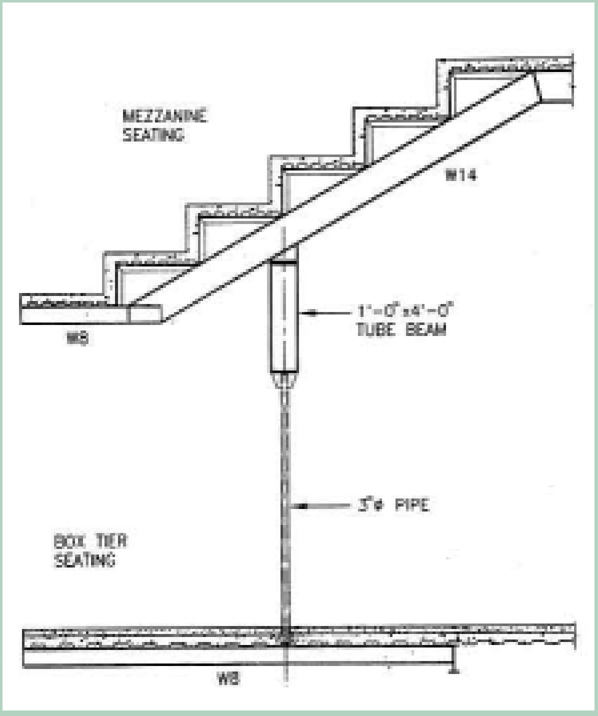
resulting in relatively inexpensive foundations. In fact, slab-on-grade construction could be used throughout, even where higher concentrated loads occur at the orchestra lift pit and the counterweight pit.

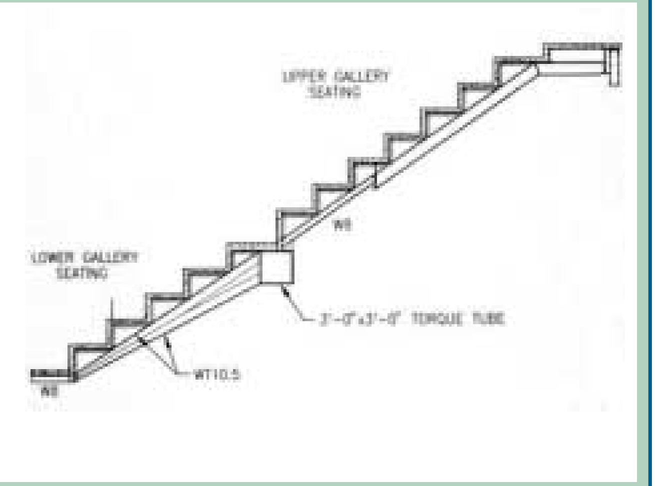
Street elevation changes of several feet around the perimeter of the building resulted in numerous changes in finish floor elevation at the Orchestra Level to accommodate required public and service entrances. The floor system consists of concrete on metal deck.

Detailing of the steel was very complex to accommodate a variety of slopes, steps and changes in elevation outside the audience chamber. Inside, however, was no less complex, with parterre seating in the rear configured in a horseshoe shape in plan, intersecting with orchestra seating that generally slopes from rear to front, much like a movie theater. The structure at the 60'x120' stage was recessed to accommodate wood strip flooring. A 16'x40' trap area, designed to be completely demountable to accommodate various stage productions, was constructed within the stage floor. Fabricator was AISC-member Steel Service Corporation in Jackson, MS, and detailer was AISC-member Neubecker Detailing Co., Ft. Worth. General contractor was Linbeck Construction Co.

## Box Tier and Mezzanine Seating

Main entrances occur at the northeast and northwest corners of the building into lobby areas, which have domed roof structures. Once inside either lobby, grand stairs lead up to the Box Tier seating level, which consists of seating divided into approximately 8'x10' sections, or boxes, which have private entries from the main public corridor. Design for the structural support of the Box Tier seating was complicated by the need to not only have it cantilever for the full depth of the boxes, but also in that it needed to be hung from the




*Shown at left is structural framing supporting the Box Tier and Mezzanine seating. Pictured above is structural framing supporting Upper and Lower Gallery seating.*

structure above in order to provide column free space for the parterre seating below.

The horseshoe configuration added additional difficulty. Sightline requirements dictated a shallow structure, limiting steel beam depth to 8". The structural solution was the introduction of a 1'x4' tubular beam fabricated from A572 Gr. 50 steel plate that curved in plan and varied in elevation. The tube beam was located immediately beneath the framing for the mezzanine seating, which cantilevered over the top of the beam.

Pipe sections, 3" in diameter, were hung from the tube beam to provide support for the W8 floor beams at the Box Tier level. The tube beam was supported by only two columns in the audience chamber, which were positioned at the rear of the parterre seating area. As a result of this unique framing solution, sightlines within the structure were preserved. Staad-III software was used for the design of the project.

### Upper & LowerGallery Seating

One of the biggest structural framing challenges on the project occurred at the Upper and Lower Gallery seating area. Typical for performance halls, the Lower Gallery seating had to cantilever over the Mezzanine seating. However, a suitable back-span condition for the cantilever was not available due to architectural constraints.

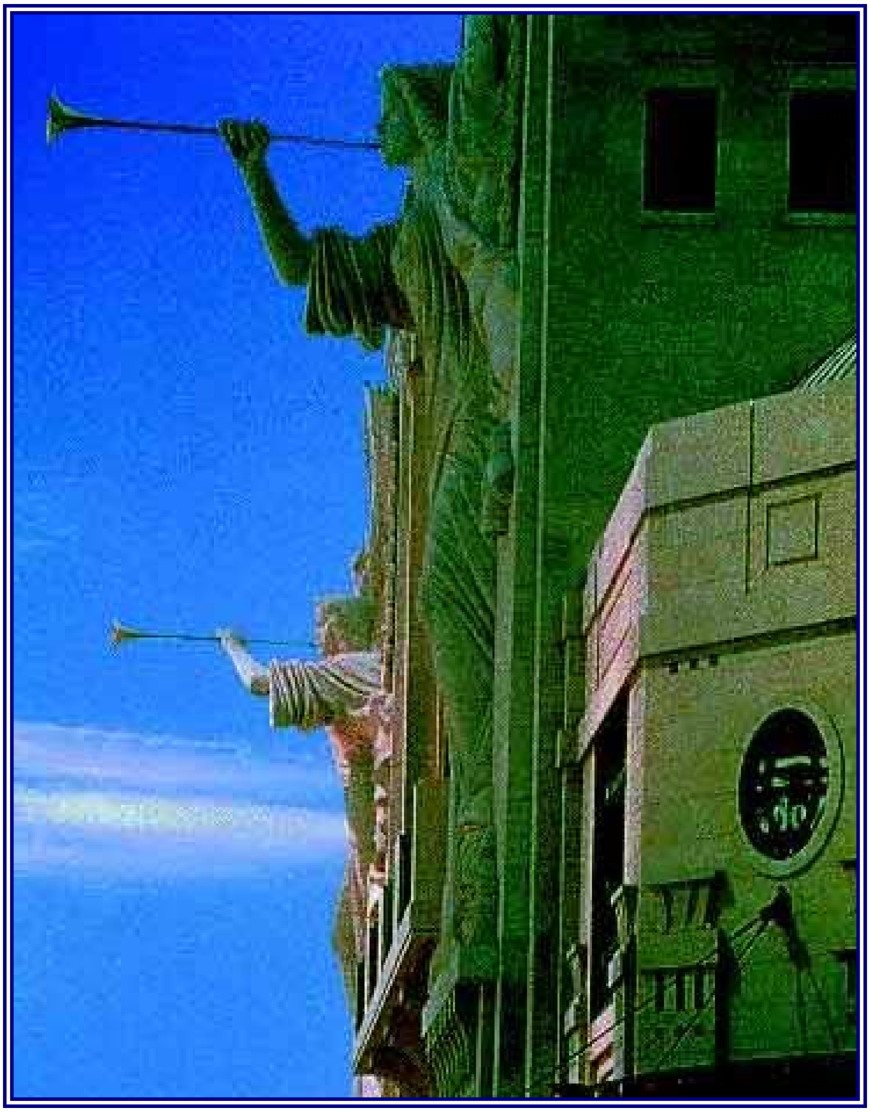
Structural beam depth in the area of the back-span was limited to 8" to accommodate the ceiling of the large public space below. To solve the problem, a 3'x3' torque tube was designed to resist the cantilevered loads. Much like the 1'x4' tube beam below, the torque tube was fabricated from A572 Gr. 50 steel plate, was curved in plan and varied in elevation. And as with the tube beam, it curves to follow the horseshoe geometry. The torsion accumulated in the torque tube is resisted by two pairs of columns located at the back of the Mezzanine seating. To further complicate the problem, these column pairs also had to be transferred out of the Mezzanine level to accommodate a public corridor below.

### Auditorium Roof Framing

The ceiling plenum over the audience chamber houses a number of functions and is generally very crowed. The space is predominantly used for mechanical ductwork to supply air to the audience chamber. In addition, an extensive network of catwalks is required to provide access to acoustical reflector panels, show lighting positions and general maintenance. On top of this, the ceiling construction utilizes thick plaster to provide the necessary acoustical environment—requiring more structural support than conventional ceiling construction.

The structural framing solution to accommodate these requirements includes 12'-deep trusses spaced at approximately 40' on center and spanning the width of the audience chamber—about 92'.

Roof construction is conventional metal deck on steel beams;



however, the acoustician needed to provide a sound barrier at the roof and required that a 4' air space be provided below the roof. Immediately below this space, he specified a 100 psf slab. The required mass was provided by introducing a composite beam framing with a 9-1/2" thick slab consisting of 6-1/2" of normal weight concrete on a 3" metal deck. This framing level occurs within the depth of the main roof trusses.

The mechanical ductwork runs immediately below the acoustical roof slab within the remaining depth of the roof trusses. Once in place, the ductwork would not allow for ceiling or catwalk hangers from below to reach the acoustical slab framing above. Therefore, another level of framing was introduced at the roof truss bottom chord elevation. This framing consisted of beams only, arranged in plan to support hangers from suspended catwalks and plaster ceilings below.

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