The new home of the Guthrie Theater, in Minneapolis, was designed by the French architect Jean Nouvel and pays homage to the mill industry that once occupied its site with spires that emulate smoke-stacks, a cantilevered walkway that resembles grain elevators, and a cantilevered, elevated lobby whose golden light matches a nearby Gold Medal Flour sign. The curved form of the thrust theater, *above,* mirrors adjacent grain elevators and appears to float in space, its structural supports concealed behind billboards that illuminate images of past performances.

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Setting the Stage

The new home of the Guthrie Theater, in Minneapolis, replaces a single-stage venue with an intriguingly complex performance hall that includes three separate stages, an ethereal elevated lobby, and what may well be the longest occupiable cantilevered space in the world. **By Robert J. Quinn, P.E.**

Jim Gallop, both

Jim Gallop.

The architect resolved the problem of blocked views by raising the theaters above the street level. For the thrust theater, this required the raker beams that cantilever beyond their supporting columns. An elevated walkway called the production link connects a scene shop across the street to the theater itself. The link was designed to accommodate large sets carried on forklifts. A pair of 6 ft (1.8 m) deep, 100 ft (30.5 m) long plate girders support the production link.

The new Guthrie Theater complex is located in the old mill district in Minneapolis on the banks of the Mississippi. This $125-million project not only replicates the renowned thrust stage that was the signature element of the original (1963) theater building but also adds two stages of a more traditional type, giving the performance hall the flexibility to present a greater variety of plays. The new facility also consolidates all of the Guthrie's operational functions into state-of-the-art spaces. Designed by the French architect Jean Nouvel, the building offers several unique architectural features—including its signature "endless bridge," believed to be the longest occupiable cantilevered space in the world.

Strategic planning for the new facility began in 1997, when the theater's artistic director, Joe Dowling, began to contemplate the future of the Guthrie Theater and concluded that to be successful in the 21st century several program requirements would have to be implemented but that simply expanding the original facility would not be the solution. Dowling and the Guthrie's board of directors decided that several objectives would have to be satisfied: functions that were being carried out in multiple locations would have to be consolidated in order to provide a more efficient and economical operation; the theater would have to be able to offer a more comprehensive range of dramatic productions in a multitheater complex; dedicated educational facilities would be required for theater production training; patron and guest amenities would have to be upgraded to make them universally accessible; and the project would need to act as a catalyst for adjacent property development. Furthermore, a renowned architect should be commissioned to design what was hoped would become a destination for international patrons. Nouvel was chosen, and his firm, Paris-based Ateliers Jean Nouvel, worked with the local architect of record, Architectural Alliance, of Minneapolis, to create a dramatic design that satisfied all of the owner's requirements. The project team included Ericksen Roed and Associates, of St. Paul, Minnesota, as the structural engineer of record, and McGough Construction Company, also of St. Paul, as the construction manager. The theater project was funded by a combination of state bonds—which accounted for $24 million—private financing, and a capital campaign.

The purchase of the land at the new location was negotiated with the City of Minneapolis. The site had been primarily used as a railway yard for the flour mill industry, and many of the former mill structures remain. Recently the site has also been used to provide parking lots. In addition to the mill structures, the site is surrounded by museums, restaurants, a new city-owned, 1,000-car parking facility, a parkway, and a riverfront. A park exists on a part of the new site that has been designated for future expansion. Condominiums have been built within adjacent mill structures, and others are under construction nearby.

Nouvel wanted to take advantage of the setting near the banks of the Mississippi by offering grand views of the rushing river, St. Anthony Falls, the Stone Arch Bridge—recognized by ASCE's National Historic Civil Engineering Landmark Program—and the elegant Hennepin Avenue Bridge. But the structure is separated from the river by the parkway, and views from grade level are blocked by bluffs. Nouvel's solution was to raise the functional area of the building by 36 ft (11 m), providing public lobby spaces that offer spectacular views of the river and bridges as well as of the mill buildings and downtown Minneapolis.

The 285,000 sq ft (26,476 m^2) facility houses three theaters; a 1,100-seat thrust stage theater intended to replicate the original structure, which was designed by Sir Tyrone Guthrie, Tanya Moiseiwitsch, and the architect Ralph Rapson; a 700-seat proscenium stage theater with rows of seats and a "picture frame" stage opening; and a studio theater with 250 movable seats. The building forms are intended to evoke images of the mill industry. The curved form of the exterior of the thrust theater reflects that of the adjacent grain elevators. The production "link"—a path for transporting sets—the endless bridge, and the long escalators are reminiscent of grain conveyors. And three light-emitting diode (LED) masts for displaying signs that rise to heights of 80 ft (24 m) are situated on each of the three main building forms, suggesting smokestacks.

The design intent was for the building to appear to float above the street level. The exterior color of the entire facility is a deep blue, which creates an illusion that the building disappears in the evening while landscape lighting illuminates phantomlike images of past performances on the exterior skin, which seems to hover in space. To create this effect vertical structural supports are hidden behind billboards below the body of the thrust theater.

From the stair-stepped soffit of the thrust theater, a boxlike projection is suspended and cantilevered beneath "alpine slope" seating. The studio theater is located near the top of the complex and includes a lobby extension that is cantilevered to capture river views and extends around the structure to offer views of the city as well. This tinted glass "yellow box" was inspired by the views Nouvel experiences as he skis the Alps wearing goggles that are tinted yellow. This extended lobby features a glass floor, enabling a beam of light from the roof below to illuminate the space at night with a bright yellow glow not unlike that of the signs for Gold Medal Flour on the nearby grain elevators.

The scenery shop, which is situated atop the new city-owned parking garage, is connected to the performance building by the production link. The cantilevered endless bridge projects from the face of the building and extends 175 ft (53 m) toward the river, 55 ft (16.75 m) above the parkway below. A 15 by 17 ft (4.5 by 5 m) window near the end of the bridge can be opened by hydraulic jacks with the turn of a key so that patrons can more fully experience the cascading waters of St. Anthony Falls.

The interior public spaces of the building are finished with images of past theater performances; some have been silk-screened onto the walls and ceilings, and some are illuminated from behind in holographic fashion.

The structural framing systems were determined by a combination of factors, including fire ratings, long-span floor and roof requirements, long-span transfers, curved and rectilinear building forms, finished floor requirements, acoustic requirements, floor-to-floor height limitations, possible construction approaches, vibration mitigation, and exterior wall support requirements.

The acoustic requirements and the placement of the scene shop above the parking facility effectively define the structure as three buildings. One is the scene shop itself. One encompasses the thrust stage theater—an audience chamber and adjacent lobby as well as administrative offices and a restaurant. And the third comprises the proscenium stage theater with its audience chamber and adjacent lobby; the studio theater with its adjacent lobby (the yellow box), the production link, the endless bridge, and a gift shop; and the common lobbies, ticket windows, administrative offices, dressing rooms, a back room for the vertical transportation systems, a preshow dining room and lounge, a VIP lounge, and rooms for costumes, props, rehearsals, mechanical equipment, electrical equipment, an actors' lounge, and classrooms.

An acoustic isolation joint is used to separate each of the theater chambers from adjacent spaces to control noise and vibration. The acoustic consultant required that a 3 in. (76 mm) air space separate the performance areas from areas that create noise and vibrations, including the vertical transportation systems, lobby spaces, loading dock, restrooms, classrooms, and building support systems. Several levels of mechanical rooms are located directly behind both the thrust and proscenium stage walls. The stage house walls are 10 in. (254 mm) thick and are of cast-in-place concrete. A second 10 in. (254 mm) thick concrete wall surrounding the stage walls supports the floors at the back of the house. These walls are separated by a 3 in. (76 mm) air space to provide the required acoustic isolation. Structurally the walls are both bearing and shear walls.

In the thrust theater the acoustic joint extends from the proscenium wall to the building exterior at each end of the stage. The joints align vertically through several floor levels and the roof. Short-span steel framing bridges the acoustic joints in several locations at each level. These beams are lightly loaded and are supported on neoprene slide bearing pads, which provide the required acoustic isolation.

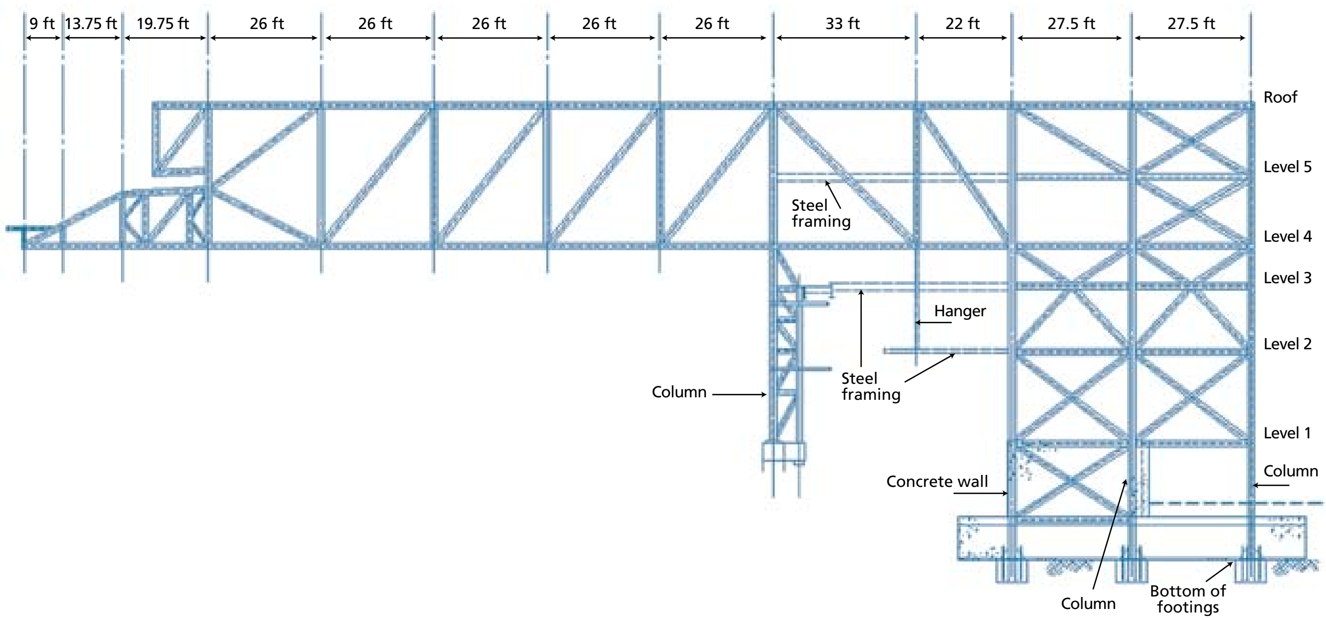
The acoustic joint for the proscenium theater is more complex. It runs vertically at the double stage wall, extending to the back of the audience chamber from each sidewall of the stage, where it terminates at the location of the proscenium lobby's acoustic wall. There was no need for the joint to exit the building's exterior wall, but it does extend vertically through the auditorium roof. The joint surrounding the stage is not extended through the classroom, studio theater, or roof levels above. Instead, it extends horizontally over an acoustic cap formed by 3.5 in. (89 mm) of concrete of normal weight atop a 3 in. (76 mm) metal deck that is supported by the stage-rigging beams. This joint does exit through the exterior wall at the proscenium opening location and above the auditorium roof as well.

The studio theater also is acoustically treated. It has a 1.5 ft (0.5 m) total floor thickness consisting of a 4.5 in. (114 mm) concrete slab on a 3 in. (76 mm) metal deck supporting a 2.75 in. (70 mm) isolation mat, a 4 in. (102 mm) concrete slab, and a 3.75 in. (95 mm) sprung floor. The surrounding masonry walls also are designed for acoustic isolation. An acoustic "guillotine" wall separates the theater lobby from the performance room. This wall can be raised or lowered from the roof framing by electric motors. The roof beams support a 4.5 in. (114 mm) concrete slab of normal weight over a 3 in. (76 mm) metal deck.

The site on which the theater was to be constructed consisted of 25 ft (7.6 m) of fill and glacial till above limestone. The foundations were designed as drilled piers that extend to the limestone with an allowable bearing pressure of 100 ksf (4,788 kPa). The limestone layer is approximately 23 ft (7 m) thick. A 4 ft (1.2 m) layer of shale separates the limestone from a layer of sandstone below. Some years ago a 15 ft (4.5 m) wide by 10 ft (3 m) high concrete-encased tunnel for the mill industry extending the length of the site was constructed through the shale and sandstone, the limestone forming the ceiling. Nevertheless, the geotechnical engineer determined that the proposed column loads adjacent to the tunnel and bearing on the limestone surface would not be detrimental to the theater project. Deep foundations were chosen to minimize the settlement differentials that may occur in response to the wide variations in column loads—from a few hundred kips to several thousand kips at the endless bridge fulcrum columns. Another benefit of using foundations that bear on rock is that they minimize vibrations into the theater areas from the adjacent streets, and those vibrations may have been more pronounced with shallow foundations on soils.

The signature feature of the building, the endless bridge, is covered near the building and is open to the sky at its end, where a 3 ft (0.9 m) wide counter-like structure called a viewing table is located. The 32 ft 4 in. (9.8 m) high, 35 ft (10.6 m) wide structure affords breathtaking views. Ramped floors connect the upper level of the shared lobby to the endless bridge and continue to the lower level of the shared lobby. At the lower lobby level, a 2,200 sq ft (2,044 m²) L-shaped, glass-enclosed room beneath the upper-level ramp houses a lounge for patrons. A fire escape catwalk is located beneath the bar level and is suspended from the bottom of the bridge. The catwalk is connected to the fire exit stairs inside the building, which are situated on either side of the bridge.

Elevation of Endless Bridge



Ericksen Roed and Associates

Jim Gallop,

The "endless bridge" may be the longest occupiable cantilevered space in the world, extending 175 ft (53 m) over a throughway to offer visitors spectacular views of the river, a waterfall, and the city. The cantilever employs a pair of trusses with K-shaped top and bottom chords that extend 110 ft (33.5 m) back into the structure, at the interior to 44 ft (13.4 m) high built-up fulcrum columns.

The bridge is framed as a box, a pair of trusses located 35 ft (10.6 m) apart providing the vertical support. The top and bottom chords of the box trusses employ K braces, the apex of the angle pointing outward from the building. The catwalk flooring platform is constructed of aluminum grating, and the steel angles beneath it—which also assume a K form—act as a smaller-scale version of the bracing for the bridge itself. This bracing is exposed and, when lighted, lends aesthetic appeal to the form.

The box trusses extend into the building for 55 ft (16.7 m) and then connect to—and span—a 55 ft (16.7 m) wide vertical bracing system, for a total back-span length of 110 ft (33.5 m). The vertical bracing system restrains the cantilever against vertical loads, both upward and downward, and also braces the cantilever against the swaying that may occur if the vertical loads become unbalanced.

The box trusses are supported at the building face by 44 ft (13.4 m) high built-up fulcrum columns. These columns are constructed of W14×730 sections and are reinforced with plates to form a box. They are braced perpendicular to the building by vertical trusses that engage each column. Parallel to the building face, the columns are braced at the top and bottom chords of the bridge truss, and at midheight they are braced by struts that connect to adjacent vertical braces.

At all of the lobby area levels 55 ft (16.7 m) long girders connect to end columns within the vertical bracing systems; this maximizes the dead-load ballast. Additional column loads from the adjacent buildings are accounted for by outrigger framing located perpendicular to the top and bottom chords of the box trusses. These outriggers cantilever 8 ft 6 in. (2.6 m) to each side.

The vertical brace frame columns are supported by piers that have been drilled into rock. A pair of concrete ballast pads 23 ft (7 m) wide, 10 ft (3 m) deep, and 80 ft (24 m) long engage each of the three columns in the vertical brace. The column base plates were oversized and reinforced to restrain the mass of the mat against uplift.

The ramp floors take the form of composite steel framing, the beam depths limited to provide as much height as possible from floor to ceiling in the bridge lounge. The design minimizes vibrations, and visitors to the theater do not feel the least bit uneasy even though they are standing on a floor that is hanging off the face of the building. The floor girders span to posts at the side-by-side ramps mentioned previously—known as ramp scissors—which are supported by W40 girders spanning between the bottom chords of the box trusses. The lounge is supported directly by these girders, the top flange flush with the structural deck. This structural deck supports insulation and a slab that serves as the finished floor of the lounge. The girders are unbraced from the edge of the lounge floor to the vertical trusses as they pass under the steep ramp area. The bottom flanges of the W40s match the bottom chord K

Neil Koeberg

A catwalk beneath the endless bridge employs K-shaped braces similar to those used to support the cantilevered space itself. This bracing is exposed and, when lighted, lends aesthetic appeal to the form.

bracing and are covered halfway up the web by a polymer-finished gypsum board soffit. Beyond the point at which the ramps meet, girder trusses of varying depths span the 35 ft (10.6 m) to the main vertical trusses. The depths of the top chords of the girder trusses were limited to 8 in. (203 mm) to provide adequate clearance above the escape catwalk. The bottom chord is of the W14 type and is integrated with the overall bottom chord K bracing. The web members were configured to include Vierendeel panels that provide the catwalk egress routes required by the applicable building codes. These trusses are exposed and can be seen from the lounge.

The terrace portion of the endless bridge is framed by tapered cantilevered trusses perpendicular to the girder trusses. The floor comprises reinforced concrete over a galvanized deck, and precast-concrete L shapes at the stairs support insulation, waterproofing, and a slab incorporating a system for melting snow.

The roof deck for the bridge is a 2.5 in. (63.5 mm) lightweight concrete slab over a 3 in. (76 mm) metal deck, a design that minimizes dead loads and provides the required one-hour fire rating.

The scene shop features a roof structure that offers 24 ft (7.3 m) of clearance so that sets can easily be moved through the facility. Metal, wood, and paint shops, along with mechanical equipment rooms, storage, and office mezzanines, are housed within the facility. Three lines of trolley beams are used to hoist larger materials. The fire rating requirements specify noncombustible, nonrated framing. The 115 by 224 ft (35 by 68 m) facility has two 57 ft 6 in. (17.5 m) bays using LH series joists in structural steel beam and column frames supporting a 1.5 in. (38 mm) thick metal roof deck. Mechanical ductwork was integrated into the joist web openings to minimize the overall building height. A 45 ft (13.7 m) LED mast on the roof required a pair of structural steel roof trusses designed with the same web openings as the joists. These trusses are framed at the top chords by additional structural steel bracing that acts as a horizontal truss. The overall lateral stability for the building is provided by the metal roof deck and braced frames at the exterior walls. A pair of 6 ft (1.8 m) deep, 100 ft (30.5 m) long plate girders supporting the production link are connected to columns at the performance building and supported by expansion joint bearings on stepped columns in the scene shop. A "roof" with a three-hour fire rating over the 1,000-car parking garage is actually the floor of the shop. The same design and construction teams that worked on the parking facility project also worked on the remainder of the theater project.

The production link also required a 24 ft (7.3 m) floor-to-ceiling height, and its floor was designed to accommodate a forklift with a capacity of 5,000 lb (3,175 kg) and an axle loading of 11,000 lb (4,990 kg). The floor for the path along which the sets would travel was specified as hardened concrete. The design featured a 4.5 in. (114 m) concrete slab on 3 in. (76 mm) metal deck with mild reinforcing topped by a 4 in. (102 mm) concrete slab. Owing to floor depth limitations and deck performance, the beam spacings were reduced to accommodate shallow beams spanning the 35 ft (10.6 m) link width. This floor system extended into the performance building to the doors of the thrust and proscenium stages. In the performance building, the floor-to-floor height was only 25 ft (7.6 m).

A 30 ft (9 m) clear span requirement for the lobby deck on level 5 was satisfied with an 8 in. (203 mm) precast plank and a 2 in. (51 mm) topping slab. The plank was supported on the fireproofed bottom flange of an upturned structural steel beam above the link entrance.

The roof slab is formed by 2.5 in. (63.5 mm) of lightweight concrete atop a 3 in. (76 mm) metal bond deck. The purlins are typically spaced 11 ft (3.4 m) apart but are closer—5.5 ft (1.7 m) apart—in areas where snow drifts may accumulate adjacent to the performance building. Plate girders 6 ft (1.8 m) deep spanning 100 ft (30.5 m) carry the roof. Wide-flange hangers spaced 11 ft (3.4 m) from the plate girder carry the floor.

The thrust theater makes use of the innovative design included in the original theater. The stage has a traditional proscenium opening with a narrow backstage. It is also extended by means of an irregular tonguelike form into the audience chamber, where the seating surrounds the stage in an arc of 160 degrees. This provides an intimate setting and offers patrons a variety of perspectives. The seating features a shallow lower bowl and a more steeply sloped balcony that meet at the alpine slope—at stage left—which extends from the upper seating to the stage itself. A vomitory ramp by which actors may enter or exit the stage is located beneath the alpine slope seating. The ramp is suspended beneath the soffit of the exterior of the building.

The lower bowl was created by two placements of concrete. The structural component is a cast-in-place posttensioned beam and slab. The heating, ventilation, and air-conditioning system utilizes the ceiling below as an air supply plenum. The slab includes supply ducts set on the forms at all of the seat locations. The second placement of concrete includes the treads and risers and carries the air supply ducts to the face of the risers. Posttensioned raker beams extend beyond the lower bowl seating to support the main level lobby.

The design required the thrust theater structure to appear to float in space when viewed from the exterior, and this was accomplished by moving the support columns from the building's exterior inward by 5 ft (1.5 m). This required the raker beams to cantilever beyond the supporting columns and to carry perimeter columns supporting the upper lobby and roof framing. Beneath the main lobby and seating level, administrative offices are supported by one-way posttensioned beams and slabs. The concrete columns below, which are 30 ft (9 m) tall, are very slender and are hidden by thin billboards. These columns were originally proposed as round to allow the random orientation of billboards and to make fabrication easier. But when the final column loads and billboard orientations were determined, the columns were designed to be square, which allowed them to be more slender and facilitated the billboard-girt connections.

The balcony and upper lobby are also constructed of posttensioned concrete. The treads and risers were created in a single placement with slabs and beams. The riser portion is designed as a narrow beam. The air supply is fed directly through a rectangular box cut into the riser. The tapered raker beams cantilever up to 22 ft (6.7 m) at the balcony. The posttensioned beam section minimizes cracking and long-term deflections. The alpine slope seating is designed using precast L shapes connected to structural steel raker beams.

The 10 in. (254 mm) structural concrete wall surrounding the backstage areas extends vertically 113 ft (34.4) to the backstage roof and is supported at its base by a 17 ft (5.2 m) high, 23 in. (584 mm) thick basement wall. The rigging framing is located 66 ft (20 m) above the stage. A 24 ft (7.3 m) high by 15 ft (4.5 m) wide door opening was required at the stage level for set access. The roof's structural slab framing takes the form of 4.5 in. (114 mm) of concrete of normal weight on a 3 in. (76 mm) metal bond deck to achieve the desired fire rating and acoustic performance. Moreover, the slab over the audience chamber supports an acoustic isolation system involving a slab that "floats" on isolation disks. The structural slab is supported by composite steel beams that connect to a total of nine long-span roof trusses and perimeter ring beams. The perimeter ring beams above the main seating and balcony areas are of concrete and are supported by concrete columns, while the alpine slope area ring beams are of structural steel and are supported by steel columns and cantilevered trusses.

The roof trusses above the audience chamber support a forestage gridiron, a catwalk system with light rails, an acoustic ceiling, and mechanical equipment platforms. A pair of primary trusses span from the columns at the back of the acoustic wall behind the audience chamber to a header truss that frames a loft area in front of the proscenium opening. This header truss is supported by a pair of transfer trusses that span from columns at the back of the acoustic wall for the audience chamber to the structural concrete wall at the proscenium opening. A truss spans the proscenium opening itself, supporting a 40 ft (12.2) high masonry acoustic wall, the backstage gridiron, the rigging level, and the roof composite framing for the backstage area and acoustic isolation slab. Structural steel was the choice to carry the suspended loadings for the upper lobby and the alpine slope seating, as well as for the extended vomitory. Above the alpine slope seating, a pair of trusses frame from back-span transfer trusses to another transfer truss at a chord near the building's perimeter. The pair of trusses then cantilever to the building's exterior. There, wide-flange steel hangers are suspended to carry the balcony lobby framing from the raker beams that support the alpine slope seating. Suspended from the balcony lobby framing are hangers that support a pair of trusses that carry the vomitory. The vomitory trusses cantilever beyond the hanger support and project from the building soffit. These hangers are hidden from view, so the boxlike projection of the vomitory appears to be without support.

The suspended upper lobby at the alpine slope is realized with composite framing. The upper lobby is located 57 ft (17.4 m) above grade and is supported adjacent to the hanger system by a beam of posttensioned concrete on a pair of 36 in. (914 mm) diameter concrete columns. The signature billboard engages these columns.

An upturned wall beam supports and separates the outer ring of the thrust stage—known as the moat area—from a removable floor area. A forestage trap room is located directly beneath this stage area. Removable stage floor panels resting on subframing designed by the theatrical equipment supplier can be lowered into this room. The moat area features floor panels that can be hydraulically lowered or raised as required. Beneath the trap room, at grade level, is a restaurant, named Cue. The kitchen area is beneath both the forestage and backstage trap rooms.

The proscenium theater is a new stage configuration for the Guthrie. Unlike the thrust stage, the proscenium stage is located entirely behind the proscenium wall. The design enables theatergoers to view contemporary performances in a picture frame setting. All seats directly face the proscenium opening, providing all audience members with the same perspective. The stage is 40 by 78 ft (12 by 24 m) and is enclosed by two walls 10 in. (254 mm) thick separated by a 3 in. (76 mm) air space. Like the thrust stage, the proscenium stage is located 36 ft (11 m) above grade. The first level is a slab on grade and houses prop rooms and rehearsal rooms. The loading dock area at the first level required the corner of the concrete walls to be removed. Additional wall openings were required at levels 1 and 2 for access into the shop and trap rooms.

Immediately beneath the proscenium theater stage and audience seating lies the second level of this theater. This level features composite framing that supports the trap room, costume rooms, and administrative offices. A 35 by 8 ft (10.6 by 2.4 m) orchestra pit is framed with wide-flange hangers. Headroom requirements limited the thickness of the slab structure beneath the pit to 8 in. (203 mm). The solution was to place W8 members flush with the concrete slab on metal deck. The deck was supported at the bottom flange of the W8s. The wide-flange beam section also resists hydraulic jack loads.

The costume room is located beneath the sloped seating area. A suspended acoustic ceiling is sloped to match the seating. Beyond the high wall area of the costume room, along a corridor wall, a pair of full-story trusses have been placed on the same grid, spanning from level 2 to level 3. These trusses are 15 ft (4.5 m) high and 48 ft (14.6 m) long and are supported on columns and spaced 12 ft (3.6 m) apart. The web member configuration was designed to allow access from the corridor to offices. These trusses carry loads from the level 2 costume room and offices, the level 3 offices, the level 4 proscenium theater lobby, the auditorium seating raker beams, the balcony, a control room, stair levels, a concrete acoustic cap, a 30 ft (9 m) high masonry acoustic wall, and roof framing, including long spans at the audience chamber with catwalks and ceiling panels.

The auditorium seating comprises precast Ls supported on structural steel beams. The balcony levels feature W16 steel beams cantilevered from columns and coped at their ends to form a WT section that has the same depth as the precast tread, which is supported at the bottom flange. The auditorium roof is constructed of composite beams and a 4.5 in. (114 mm) concrete slab on a 3 in. (76 mm) deck. For acoustic purposes, a 1.5 in. (38 mm) topping slab is placed over the slab, and an additional acoustic gypsum board ceiling is suspended from the roof framing. The primary framing members of the auditorium roof are W40 members spanning 72 ft (22 m) from a proscenium opening truss to the back of the auditorium. In addition to supporting a catwalk, sound-reflecting panels, and an acoustic ceiling, these W40 members were designed to withstand drifted snow loads. The live-load deflection for these beams is limited to 0.75 in. (19 mm) In addition to the auditorium roof, the proscenium opening truss supports the rigging level and acoustic cap, the gridiron over the stage, and a 25 ft (7.6 m) high concrete masonry acoustic and exterior wall.

The areas in the back of the house behind the stage and acoustic joints are framed with composite beams and slabs on steel columns, concrete bearing walls, and braced frames. The escalators carry patrons from the level 1 lobby up 47 ft (14 m) to level 4, which is the common lobby for the proscenium and thrust theaters, the bridge bar, and the ramp up to

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The endless bridge is covered near the building but is open to the sky at its end, with steps leading down to a safe viewing area. Inside, ramps lead from lobby areas to the cantilevered space.

the endless bridge. The total run for the escalator is therefore 100 ft (30.5 m), requiring midspan support framing for the escalator trusses. Classrooms are accommodated on level 8, directly above the proscenium stage rigging and acoustic cap and below the studio theater.

The studio theater is intended to facilitate experimental theater productions. This stage is located at the top of a tower at level 9, the site of the "yellow box." This extension is an all-glass enclosure of 15 by 48 ft (4.5 by 14.6 m) and is situated 132 ft (40 m) above level 1. The lobby features a 5 by 10 ft (1.5 by 3 m) glass floor panel and a skylight of similar size. The enclosure is lighted from within, and a light also shines up through the floor panel from the auditorium roof 56 ft (17 m) below, effecting a lanternlike glow at night. The extended lobby cantilevers 15 ft (4.5 m) from one side of the building face and 12 ft (3.6 m) from another, like one box extending out of another. This provides guests with dramatic views of the river and downtown. This double cantilever is supported by plate girders and W40 beams at the floor and roof levels. The cantilevered members perpendicular to the building face have a back span that engages vertically braced frames. One pair of the cantilevered members are framed over the proscenium stage opening at their fulcrum.

A three-story wall truss carries the classroom space at level 8, along with the studio theater floor, a control room and masonry acoustic wall, and long-span roof and rigging framing above the acoustic joint and the proscenium stage opening below. This wall truss features a one-story opening at one end to accommodate the cantilevered lobby.

The building was substantially completed and occupancy permits were obtained in March 2006. The owner started the process of moving offices and equipment into the space at that time. The official opening was June 24, 2006.

The new venue of the Guthrie Theater certainly presented unique challenges to the engineers. Involvement in the design process from the earliest planning stages through the public opening enabled the engineers to provide a design that satisfied the complex architectural intent and ultimately met the owner's objectives. ■

Robert J. Quinn, P.E., is a principal and vice president of Ericksen Roed and Associates, of St. Paul, Minnesota.

Project Credits

Owner: Guthrie Theater, Minneapolis

Design architect: Ateliers Jean Nouvel, Paris

Architect of record: Architectural Alliance, Minneapolis

Structural engineering: Ericksen Roed and Associates, St. Paul, Minnesota

Construction: McGough Construction Company, St. Paul, Minnesota

Project adviser: Keewaydin Real Estate Advisors, Minneapolis

Mechanical and electrical engineering: Michaud Cooley Erickson, Minneapolis

Geotechnical engineering and materials testing: Braun Intertec, Bloomington, Minnesota

Theater consultant: Fisher Dachs Associates, New York City

Acoustic consultant: Talaske Group, Inc., Chicago