Bel Canto

A modern interpretation of a traditional performance venue, the design of the new Margot and Bill Winspear Opera House, in Dallas, emerged from the close cooperation on the part of engineers, architects, and acoustical and theatrical experts that enabled them to overcome such noise and vibration challenges as the structure's proximity to a major freeway and its location directly beneath the flight path of a Dallas airport.

By Robert L. Reid

JUST AS THE SUCCESS OF AN OPERA or other theatrical performance requires cooperation on the part of the actors, the director, the musicians, and the various artistic and technical experts who create the costumes, scenery, and other features of the production, so too does the launch of a new performance venue depend on close collaboration by the engineers, architects, and acoustical and theatrical experts who design the building's various spaces and features. In the case of the Margot and Bill Winspear Opera House, which opened in Dallas in mid-October, the design is based on a traditional opera house style, but it had to overcome the very modern noise and vibration challenges of a site near a major freeway and directly beneath the flight path of the airport Dallas Love Field.

Designed by the London office of Foster + Partners, which is led by the Pritzker Architecture Prize–winning Norman Foster, the Winspear will host performances of opera, ballet, and Broadway-style productions. The London office of Buro Happold and the Dallas office of Thornton Tomasetti served as respectively the design engineer and the engineer of record. Houston-based Kendall/Heaton Associates, Inc., was the architect of record. London-based Sound Space Design was the acoustical consultant, and Theatre Projects Consultants, Inc., of Norwalk, Connecticut, was the theater design consultant.

The Winspear project was completed over a six-year period of design and construction at a total cost of $197 million, including site work, land and government fees, and other costs. It is located within a new, 10 acre downtown area called the Elaine D. and Charles A. Sammons Park, which is part of the AT&T Performing Arts Center,

NIGEL YOUNG/FOSTER + PARTNERS

Clad in bright red glass, the central portion of the Margot and Bill Winspear Opera House, in Dallas, represents a modern interpretation of a traditional performance venue. A sort of bel canto (beautiful singing in Italian) in concrete, it rises like a high note above the building's six-story lobby and the surrounding steel-framed solar canopy.

The curving southern exterior of the opera house's auditorium, which is called the Red Drum because of its distinctive glass cladding, is lined with a series of cantilevering concrete walkways that act primarily as corridors but also help to stiffen the cast-in-place walls.

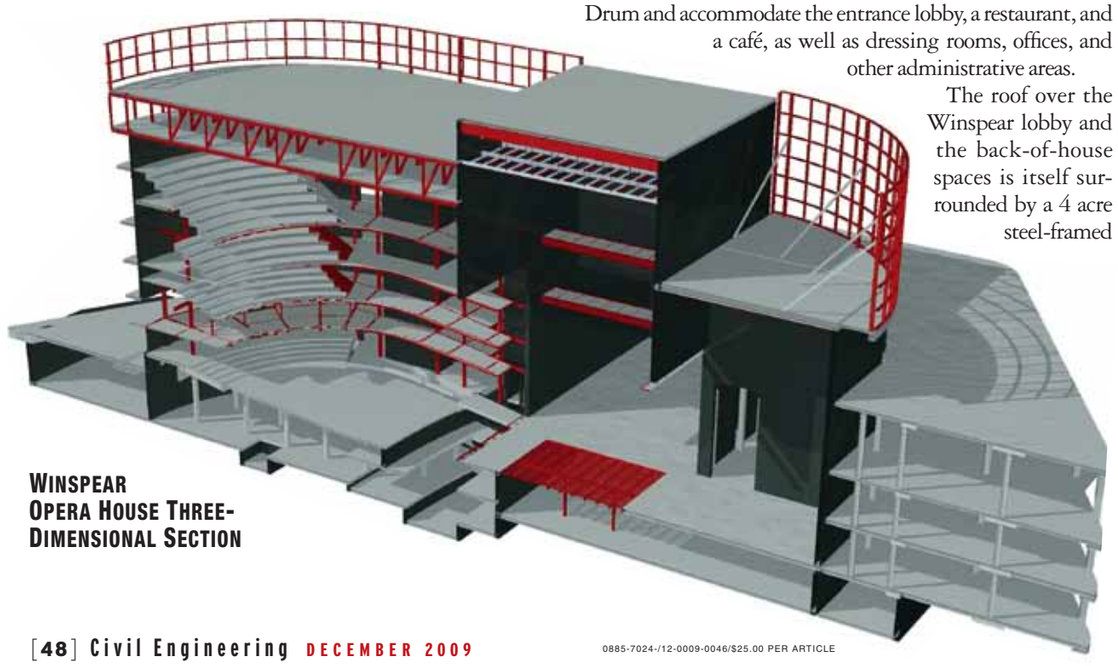
a complex of venues for music, theater, dance, and other performances that are operated by the Dallas Center for the Performing Arts Foundation, explains Douglas Curtis, the foundation's vice president of design and construction. The main buildings within the center—the Winspear and the Dee and Charles Wyly Theatre, a 12-level structure that opened at the same time as the opera house—together with a new, three-level underground parking garage and a one-level underground garage that is under construction, are owned by the City of Dallas. The AT&T Performing Arts Center also includes a new outdoor amphitheater, the Annette Strauss Artist Square, scheduled to open in 2010. An earlier version of the Strauss amphitheater at the site of the Winspear was demolished to make room for the opera house, and it is being reconstructed as a new space designed by Foster + Partners.

Other Dallas cultural and artistic institutions are located in close proximity to the Winspear and the Wyly as part of the 68 acre Dallas Arts District, which surrounds the AT&T Performing Arts Center.

The central and most visually stunning element of the Winspear is the 43,000 sq ft auditorium and stage house space. Officially known as the Margaret McDermott Performance Hall, it is also called the Red Drum for the dramatic red glass cladding that covers its curving exterior, which is roughly oval in plan. The building is aligned in a slightly skewed north–south direction, the entrance lobby roughly facing south.

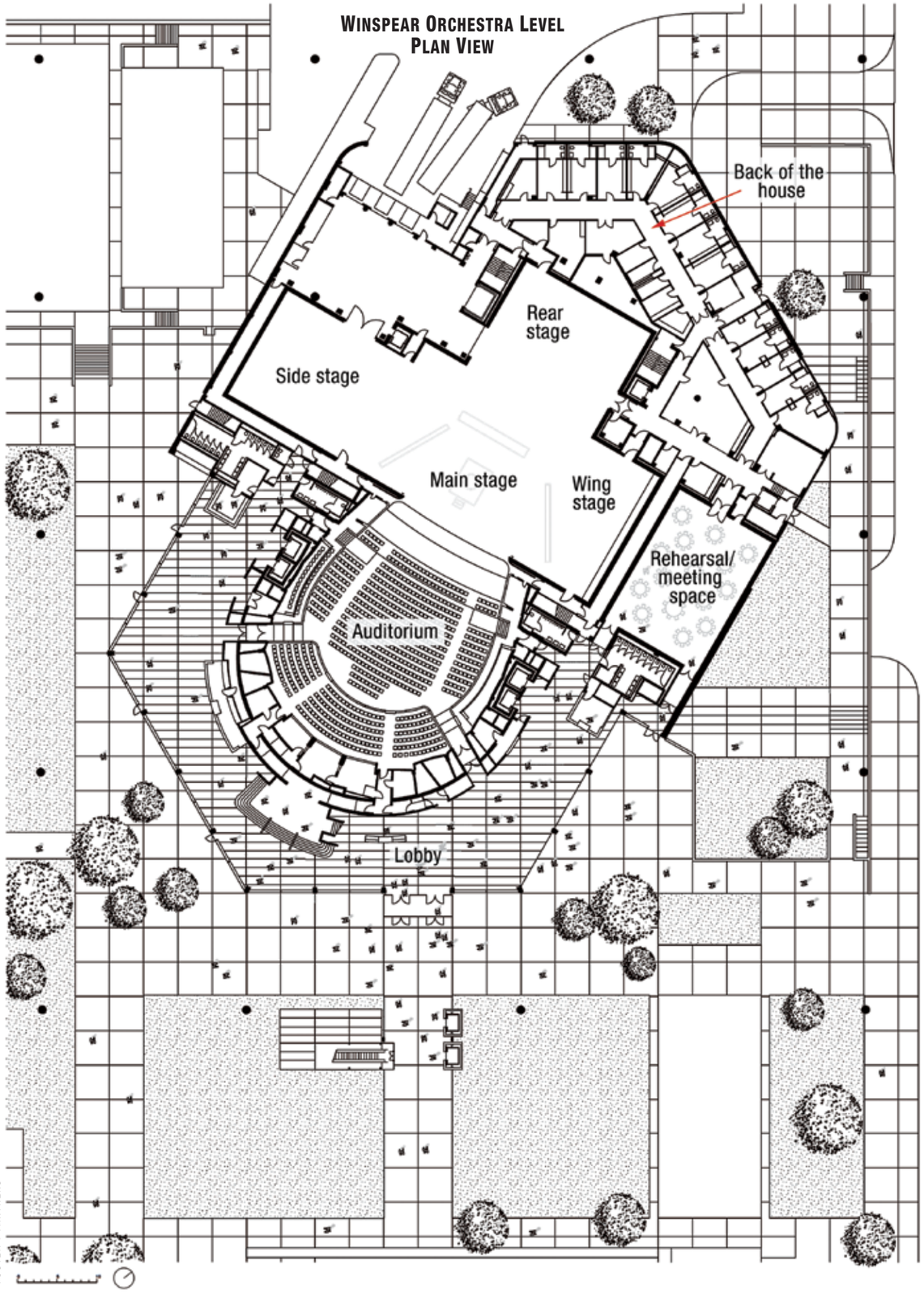
Constructed primarily of sound-attenuating materials and masonry beneath the red glass skin, the Red Drum can be seen as embodying bel canto (beautiful singing in Italian) in concrete as it rises like a high note from the at-grade orchestra level seating to a height of approximately 104 ft. Its upper portion extends roughly 44 ft above the steel-framed roof that covers the Winspear's six-story, 28,500 sq ft glazed facade and the back-of-house spaces. These spaces surround the Red Drum and accommodate the entrance lobby, a restaurant, and a café, as well as dressing rooms, offices, and other administrative areas.

The roof over the Winspear lobby and the back-of-house spaces is itself surrounded by a 4 acre steel-framed



WINSPEAR OPERA HOUSE THREE-DIMENSIONAL SECTION

PHOTO: IWAN BAAN. *TOP:* BURO HAPPOLD. *BOTTOM*



FOSTER + PARTNERS

0885-7024-/12-0009-0046/$25.00 PER ARTICLE

© 2009 American Society of Civil Engineers

solar canopy 63 ft tall that features fixed metal louvers designed to shade the opera house's facade—officially known as the Annette and Harold Simmons Signature Glass Facade—and an outdoor terrace and other open spaces beneath the canopy, including the Annette Strauss Artist Square.

The Winspear canopy was designed to accommodate the rigging loads of the lighting and other theatrical systems for the Strauss amphitheater, notes Leo Galletta, Ph.D., P.E., Thornton Tomasetti's principal in charge of the Winspear project. More than 280 trees were successfully transplanted to new sites as part of the demolition of the original Strauss amphitheater, Curtis adds.

The eastern side of the Simmons facade features a retractable section 84 ft wide composed of three glazed panels that by means of a screw drive mechanism in the supporting columns and a concealed motor can rise to a height of 23 ft, thereby opening the Winspear lobby and other portions of the building to the Sammons park, says Clifford Brade, P.E., Thornton Tomasetti's principal project engineer. Nine separate versions of opening mechanisms were considered, including vertical, horizontal, sliding, and folding options, before the final version was selected, explains Clive Fussell, CEng, an associate structural engineer in Buro Happold's London office.

The Winspear auditorium features four sloping balconies above the orchestra seating level that are designed to make audience members feel close to the stage. An enormous chandelier formed from acrylic rods can be retracted into the ceiling via cables so that it does not obstruct sight lines.

Also located on the eastern side of the Winspear is the 200-seat Nancy B. Hamon Hall, a space designed to accommodate smaller performances, rehearsals, classes, and meetings.

Creating the opera house required careful coordination on the part of the members of the design team, which led to several visits by team members to other opera houses and performance spaces. Theatre Projects, which has offices in London and Düsseldorf, Germany, took key donors, members of the Dallas Center for the Performing Arts Foundation, and Foster + Partners architects on a tour of major European opera houses, especially the Nationaltheater of the Bayerische Staatsoper, in München (Munich), Germany. Foster + Partners also carefully studied the design of other opera houses in the United States. Buro Happold, which was responsible for analyzing the potential movement of crowds through the Winspear, even sent its engineers with a video camera to study London's Royal Opera House "to understand the sort of typical behavior of the operagoer" explains Fussell.

The Buro Happold team filmed audience members at a performance of the Royal Opera as they arrived, departed, and moved around the building during the intermissions. Team members also counted the number of people who moved past certain points in the building. The data were used by a team in Buro Happold's headquarters, in Bath, United Kingdom, to generate three-dimensional flow rate models using the firm's proprietary Software Modelling Analysis Research and Technologies system. The software team was led by Shrikant Sharma, an associate in the Bath office, Fussell adds.

The Norwalk, Connecticut, office of Theatre Projects provided additional analysis of expected audience movements through the auditorium and other public spaces of the Winspear, which augmented the firm's other analyses of movement through the building by performers, technicians, and operations staff, as well as the movement requirements related to such performance equipment and road show gear as scenery, lighting, costumes, and props, explains Jules Lauve, a Theatre Projects associate and the firm's project manager for the Winspear.

Buro Happold engineers worked closely with Sound Space Design to determine which areas within the Winspear would need to be acoustically isolated, and Buro Happold coordinated its design work with Michael Nishball, a principal of Theatre Projects and the director of technical production for the firm. For instance, Nishball and the engineers toured at least two college-based performance spaces that Theatre Projects had worked on previously, poring over a structural guidelines report that Theatre Projects had generated to help work out the details of the steel framing grid that would be suspended over the Winspear's stage to carry the loads of rigging and lighting equipment. "We did a lot of design work in the backseat of my car while we were driving around New England trying to sort out certain details for the project," Nishball recalls.

The design of the Winspear represents a 21st-century reinterpretation of the horseshoe-shaped configuration that has long been used in opera houses in both the United States and Europe, notes Curtis. But the new venue also utilizes modern materials, among them the Red Drum's vibrant cladding, the glazing that maximizes transparency in the Simmons facade by virtue of its extremely low iron content, and the extensive finishes in stainless steel and aluminum, to create a structure that will look contemporary even 20 years from now, Curtis predicts.

Although the starting point of the design was the traditional horseshoe form for the auditorium, the architects then added the "dramatic vertical stacking" of four balcony levels above the orchestra level to ensure "that the audience is as close as possible to the stage, thus enhancing the impact of the performance," according to the architect's statement from Foster + Partners. A distance of 88 ft 9 in. separates the stage from the balconies, which is "less than the distance between home plate and third base on a baseball field," the statement added, in what might be the only recorded comparison of such diverse entertainment venues.

At 2,200 seats, a number that can be expanded to 2,300 if necessary, the Winspear's seating capacity is roughly one-third smaller than that of the previous home of the Dallas Opera, the 3,400-seat Music Hall at Fair Park, which is located within Dallas's Fair Park, a 277 acre complex of entertainment and cultural attractions on the outskirts of the downtown area.

But being smaller or, more precisely, being "designed to be as intimate as possible," according to the Foster + Partners architect's statement, was one of the main reasons for constructing the Winspear. The other critical goal was to create the best possible acoustics in a contemporary "world-class facility," notes Curtis.

The compactness of the Winspear auditorium, together with extensive studies that were conducted on the potential sight lines and the emphasis on the acoustics, ensured that "there wouldn't be a bad seat in the house," explains Galletta. The geometry of the balconies was reworked several times during the design phase

A series of so-called flying beams within the lobby span the distance between the Red Drum wall and the steel columns of the glazed facade to support the mezzanines and the Grand Staircase. Each beam is supported on a load-bearing acoustic joint with laminated rubber isolation pads that transfer the loads but damp any noise and vibrations.

NIGEL YOUNG/FOSTER + PARTNERS. *BOTH*

© 2009 American Society of Civil Engineers

The six-story facade of the Winspear features a retractable section 84 ft wide composed of three glazed panels. Located within a new public park, the building is surrounded by a reflecting pool that is shaded by the canopy, outdoor seating for a café, and a series of paved pathways lined with trees and other plantings. Lawns that feature gardens of native perennials and grasses enhance the setting.

NIGEL YOUNG/FOSTER + PARTNERS

to optimize the sight lines and to minimize the structural depth of the balconies for visual and acoustic reasons, Galletta adds. A thin profile for the balcony structures enables the audience members seated in the farthest rows to hear the music and the singing and also to see the top of the proscenium wall that frames the stage. They can enjoy an uninterrupted view of tall scenery and read the supertitles that are projected onto the proscenium during performances, notes Robert Essert, the director of Sound Space Design.

One of the greatest challenges for the design team involved the side balconies in the auditorium, which slope toward the stage at angles that vary from the rear of the auditorium to the proscenium wall, notes Lauve. "Horizontal balconies would have been far easier," Lauve says, "but would have been an unfortunate and drastic departure from historical precedence and the proven advantages of sloping side balconies." Sloping balconies markedly improve the sight lines and the perceived scale of the artists onstage and heighten the intimacy with the audience, explains Lauve.

The balcony structures are made up of concrete slabs on metal decks spanning between sloped, cantilevered steel rakers. Because the front row is limited to a total architectural thickness of 12 in., the steel rakers feature composite steel and concrete end sections that are 8.25 in. thick and cantilever 3 ft 4 in. from the primary steel rakers, Galletta adds. Even the balcony parapets were designed for maximum acoustics, adds Essert, who explains that these railings are composed of a steel frame covered by a 1.5 in. thick layer of glass-fiber-reinforced gypsum and plaster that is molded at the front with a rippling pattern designed to best reflect the sound.

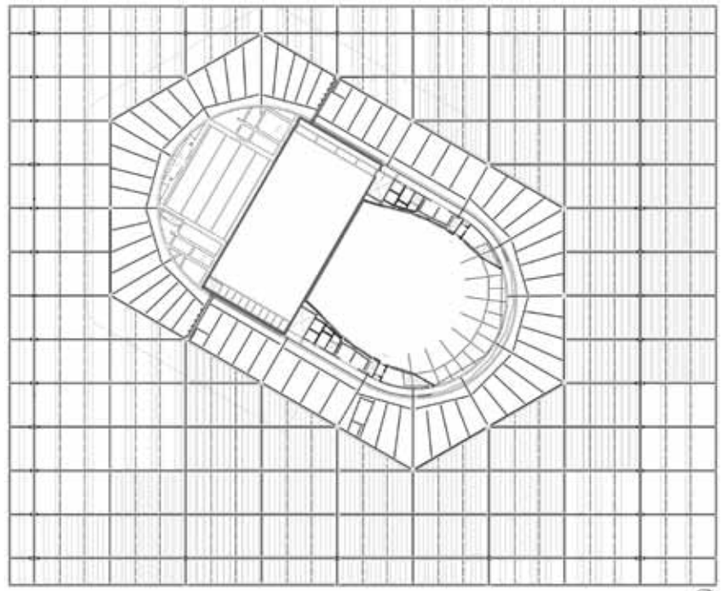
The rear walls of the auditorium also feature an architecturally scalloped form made up of curving concrete masonry unit (CMU) structures 8 and 12 in. thick on which all gaps have been filled with grout in order "to reflect the orchestra's and the singer's sound back into the room," says Essert. These grouted CMU walls also help to acoustically isolate the auditorium from exterior noise caused by the building's own mechanical systems, from aircraft that regularly fly overhead—Dallas Love Field being just 4 mi away—and from traffic noise from the Woodall Rodgers Freeway, which connects two interstate highways in the city and runs along the site's northwestern boundary.

The CMU walls alternate with walls of cast-in-place, reinforced concrete to form a double sound barrier throughout the Red Drum's auditorium and stage house spaces, the air gap between the walls ranging from approximately 6 in. to several feet for better acoustic isolation, notes Galletta. For example, the cast-in-place walls are 12 in. thick and are located outside of the CMU walls at the southern end of the Red Drum, the portion that curves around the back of the auditorium and is clad in red glass in the Winspear lobby. But around the opera house's main stage and around the wing stage, side stage, and stage spaces (see the drawing on page 49), the cast-in-place walls are 18 in. thick and are located inside the CMU walls, which are 12 in. thick at these locations, Galletta says.

The cast-in-place walls are quite tall. Indeed, the auditorium portions reach a height of 85 ft above grade and the stage portions are approximately 104 ft above grade, but the walls are relatively thin and do not include pilasters or other bracing. As a result, a buckling analysis of the type more commonly carried out for light steel structures than for concrete had to be performed to determine that the walls would support the gravity loads, Galletta says. A series of 12 in. thick concrete walkways line the exterior of the Red Drum in the Winspear lobby, cantilevering approximately 5 ft from the Red Drum wall. Although these walkways act primarily as corridors to provide audience members with access to the various openings in the auditorium, they also help to stiffen the cast-in-place Red Drum walls.

To achieve the desired levels of acoustic isolation in the performance hall, Essert says, the Winspear was designed as essentially three independent structures: the Red Drum auditorium and the stage house area; the lobby and its one-level, below-grade mechanical spaces; and the back-of-house areas that include additional mechanical spaces.

"No structure could be connected to the outside of the Drum wall without being acoustically isolated," explains Galletta. "No structure supporting the public areas or the roof—all those had to be acoustically isolated. So where we needed to transfer load to the Drum, there was a rather intricate acoustic isolation joint that was prescribed by the acoustician, and generally this amounted to laminated rubber and steel pads similar to a seismic isolation pad so they would transfer load but not transmit vibrations."



WINSPEAR CANOPY FRAMING PLAN VIEW

Two primary types of acoustic joints were used in the Winspear building. Load-transferring acoustic joints were installed wherever a structural beam requiring load transfer framed into the wall of the Red Drum, explains Brade. These include the points at which the steel beams that support the roof of the lobby meet the Red Drum wall; the load-transferring joints isolate the auditorium from any vibrations caused by heavy winds or rain on the roof or the canopy. Load-transferring joints were also used with a series of so-called flying beams within the lobby that span between the Red Drum wall and the steel columns of the glazed facade, a distance of nearly 60 ft in places. The flying beams support a series of mezzanines formed by 3.5 in. thick lightweight concrete slabs on 2 in. thick metal decks containing a restaurant and a bar. The flying beams also support the Grand Staircase, which features stone treads, open risers, and steel plate stringers. The staircase wraps around the lobby portion of the Red Drum wall to give audience members access to the upper tiers of seating. The aluminum-clad flying beams include W 27 × 178 and W 33 × 130 elements and are supported at the Red Drum wall by steel brackets welded to steel plates that are embedded in the concrete wall. Each beam is supported on a bracket with laminated rubber isolation pads.

In locations where no load transfers were required, the design used a simpler acoustic expansion joint that involves a complete separation of the building structures. Such expansion joints line the north side of the stage house wall to separate the performance hall and stage from the back-of-house structure, Brade explains. Similar expansion joints were used around the exterior of the Red Drum wall in the lobby to separate the free ends of that structure's cantilevered walkways from the mezzanines and the Grand Staircase, as well as to separate the granite-covered floor of the lobby from the Red Drum structure.

Even the elevators that carry audience members up to the various tiers of seating had to be isolated acoustically because they are located

A 63 ft tall steel-framed solar canopy encompassing 4 acres surrounds the Winspear's lobby, auditorium, and stage and the back-of-house spaces. The canopy features fixed metal louvers designed to shade not only the opera house's facade but also an outdoor terrace, an amphitheater, and other open spaces.

THORNTON TOMASETTI; *TOP:* IWAN BAAN; *BOTTOM*

within the Red Drum structure, adds Galletta. Thus, the two elevator towers, one on the eastern side and one on the western side of the auditorium, each having two cabs, were designed as independent freestanding structures that cantilever vertically for the full height of the auditorium, approximately 68 ft.

Further acoustic protection is provided by the double-slab construction of the roof that covers the auditorium. The two concrete slabs are supported by a series of seven steel trusses that are approximately 15.5 ft at the deepest point and span 120 ft in the east–west direction across the auditorium. The trusses are supported by the walls of the Red Drum. The 9.5 in. thick upper slab, which is supported on the top chords of the trusses, is formed by 6.5 in. of concrete on a 3 in. thick metal deck. The 7.5 in. thick lower slab, supported on the lower chords, is 4.5 in. of concrete on a 3 in. thick metal deck.

Using two slabs with different thicknesses is beneficial because all heavy surfaces have an acoustic weakness known as the critical frequency, which, explains Essert, is based in part on the density of the material. Since the points of critical frequency will be located in different places in the frequency scale for slabs of different thicknesses, the two slabs will work together to fill in any acoustic gaps, much like two pieces of paper with holes that do not align, Essert says.

A portion of the upper Red Drum wall constructed of grouted CMU is suspended via tube hangers from the bottom chords of the roof trusses, notes Brade. The roof trusses also support several theatrical systems, including catwalks and a spotlight booth, as well as the plaster ceiling of the auditorium and a unique chandelier system. The latter consists of more than 300 acrylic rods, each 6 ft in length but suspended at varying heights, that provide illumination with light-emitting diodes (LEDs). The chandelier is retracted into the ceiling via cables during performances, creating what appears to be a starry sky in the ceiling so as not to block the view of the stage from the upper balconies, notes Rollie Childers, a principal of Kendall/Heaton. Weighing approximately 10,000 lb, the chandelier is suspended from the trusses via a steel framework that measures approximately 40 ft in height and 40 ft in width and has horizontal members spaced at 5 ft intervals in each direction.

The fly tower is the 104 ft tall space above the stage that provides the necessary room for the lighting and scenery rigging systems. The rigging consists of counterweight flying systems, electrical winches, and manually operated rope systems. The main rigging system is located along the eastern wall of the tower ("stage left") and has been designed to accommodate horizontal and vertical force components of respectively 670 and 375 lb per linear foot, explains Brade.

According to Nishball and Lauve, the system features a conventional manual counterweight rigging system of 86 sets of lines, each with a capacity of 30 lb per linear foot, as well as a system of 18 variable-speed, repositionable point hoists at the stage grid. Each hoist is capable of moving 750 lb at 400 ft/min. Gantry systems located over the rear stage and the side stage spaces feature a dozen chain hoists, each with a lifting capacity of 1 ton.

The fly tower area also features a passive smoke ventilation system for use in the event of a fire on the stage, notes Essert. The system consists of a series of horizontal and vertical hatches that are insulated for noise control and are located in the roof structure. When opened, the hatches are designed to draw smoke out of the structure.

The 5.5 in. thick floor of the Red Drum auditorium takes the form of a 2.5 in. thick concrete slab on a 3 in. metal deck. The rakers supporting the first level of balcony seating vary in size from W 12 × 50 beams to a W 12 × 152 member and feature a maximum cantilever of 19 ft from the steel columns that are located a maximum of 12 ft from the inside of the southern end of the Red Drum wall. The typical rakers supporting the two highest balconies at the southern end of the auditorium are W 16 × 89 members. The standard column sizes are W 16 × 100 and W 14 × 132, and the elements are encased in concrete for fire protection and spaced at intervals of 13 to 15.5 ft around the auditorium and at intervals closer to 24 ft at the elevator towers, notes Brade. Beneath each seat in the auditorium, the concrete structure features a 6 in. diameter hole with a perforated disk for diffusing heated or cooled air to the audience via special plenums in the orchestra floor and balcony structures. Like the smoke ventilation system, the plenums are lined with insulation to control noise, Essert says.

Because the retractable section of the glazed facade will sometimes be open during rehearsals, thereby nullifying the sound protection afforded by the double layers of 0.5 in. thick glass panels, the auditorium features doors of heavy timber that are 3 in. thick and have solid cores to attenuate the outside noise, notes Essert.

The floor system of the lobby is formed by posttensioned concrete girders with 6 in. wide concrete pan joists and a concrete slab $4\,^5/_8$ in. thick. Framing the tall, open space of the lobby are perimeter steel columns that span vertically 60 ft and support both the roof loads and the glazed facade. The columns are W 14 × 398 members with trimmed flanges on each side for architectural reasons as well as two types of built-up shapes made from steel plate, notes Brade.

The Winspear's six-story solar canopy, a rectangle measuring 462 ft in the north–south direction and just over 378.5 ft in the east–west direction, connects to the facade's perimeter columns. The canopy is framed by aluminum-clad steel beams, primarily W 12 × 50 elements and W 36 members with varying weights per unit length, that feature a typical span of 114 ft and a longest span of 142.5 ft in a critical location on the western side of the Red Drum, notes Brade. Although various patterns were considered for the canopy, the design team ultimately selected a rectangular grid both for architectural reasons and for reasons of structural efficiency, notes Galletta.

Steel pipe columns 30 in. in diameter with 0.5 in. thick walls support the canopy frame, which cantilevers 50 ft along the southern edge.

The canopy louvers consist of 8 in. diameter steel pipes centered in aluminum panels that are 10 in. wide and 4 ft 4 in. long. The potential angles of the fixed louvers were carefully studied to maximize the amount of shading produced, and the potential deflections of the canopy were analyzed to determine the correct camber for the structure, Galletta notes. The steel pipe cores of the louvers were also designed to serve a secondary purpose, namely, to brace the canopy's beams, which substantially reduced the amount of steel required, Galletta says. Some louvers were even used primarily for bracing in locations where shading was not required.

NIGEL YOUNG/FOSTER + PARTNERS

Situated in downtown Dallas, the Winspear is part of the new AT&T Performing Arts Center, a complex of venues for music, theater, dance, and other performances. The center in turn is surrounded by a series of other cultural and artistic institutions that form part of the Dallas Arts District.

The canopy is designed to accommodate a live load of 12 psf, which includes both wind and ice loads.

Round piers of reinforced concrete located along the perimeter of the Red Drum walls and beneath critical columns and beams form the Winspear's foundations. The piers range in diameter from 18 to 48 in. and were drilled into limestone to depths reaching 20 ft. The largest piers are located beneath the columns that support the canopy on the northern, eastern, and western sides of the building, notes Brade.

A portion of the Elaine D. and Charles A. Sammons Park, which is south of the Winspear, creates a plaza level between the opera house and the Dee and Charles Wyly Theatre. It features a reflecting pool that is shaded by the canopy, as well as outdoor seating for the café. As added enhancements, a series of paved pathways lined with trees and other plantings, as well as lawns that feature natural gardens of native perennials and grasses, are located around the Winspear site. The plaza also serves as the roof of a new, three-level underground parking garage—the Lexus Red Parking—that serves both the opera house and the Wyly theater. A parking garage east of the Wyly is under construction and is expected to open in the spring of 2010.

The framing of the plaza above the Lexus Red Parking area features posttensioned-concrete girders that are 4 by 6 ft in cross section and a 16 in. thick one-way-posttensioned slab in order to accommodate a total potential live load of approximately 750 psf. The design allows for the weight of the 4 ft of soil for the plaza-level plantings and for the possibility that an emergency vehicle or other large vehicle might need to drive onto the plaza, says Brade.

The lower levels of parking are supported by concrete beams that are 22 by 34 in. in cross section. The garage framing also includes concrete columns 24 by 30 in. in cross section along the perimeter of the structure and 24 by 36 in. columns in the interior. The parking areas feature columns spaced 60 ft apart to provide a clear span between the aisles so that visitors, who must park their own vehicles, do not have to make their way around intermediate columns, explains Brade.

Although there is no direct access from the Lexus Red Parking to the Winspear, the garage features elevators and escalators to bring visitors from each lower level to the plaza, from where they can access the main entrance of the opera house via a glazed, steel-framed rain shield that passes beneath a portion of the louvered canopy.

A series of structural glass floor sections located close to the escalators provide what is essentially a three-story light well that penetrates the lower levels of the garage. It's an apt design element for audience members to experience as they approach the opera house, almost foreshadowing the way the spotlights will pierce the darkened auditorium to illuminate the stage as the curtain rises. **CE**

PROJECT CREDITS **Owner:** Dallas Center for the Performing Arts Foundation, Dallas **Architect:** Foster + Partners, London **Architect of record:** Kendall/Heaton Associates, Inc., Houston **Design engineer:** Buro Happold, London **Structural engineer of record:** Thornton Tomasetti, Dallas **Acoustic consultant:** Sound Space Design, London, with subconsultant Wilson, Ihrig & Associates, Inc., Oakland, California **Theater consultant:** Theatre Projects Consultants, Inc., Norwalk, Connecticut **Contractor:** Linbeck Construction Company, Fort Worth, Texas **Curtain wall and exterior envelope consultant:** Buro Happold, London, design consultant; Thornton Tomasetti, Dallas, consultant of record **Wind engineering consultant:** Cermak Peterka Petersen, Inc., Fort Collins, Colorado **Landscape designers:** Michel Desvigne Paysagistes, Paris; Kevin Sloan Studio, Dallas; and JJR, Chicago **Stage and chandelier rigging consultant:** J.R. Clancy, Inc., Syracuse, New York