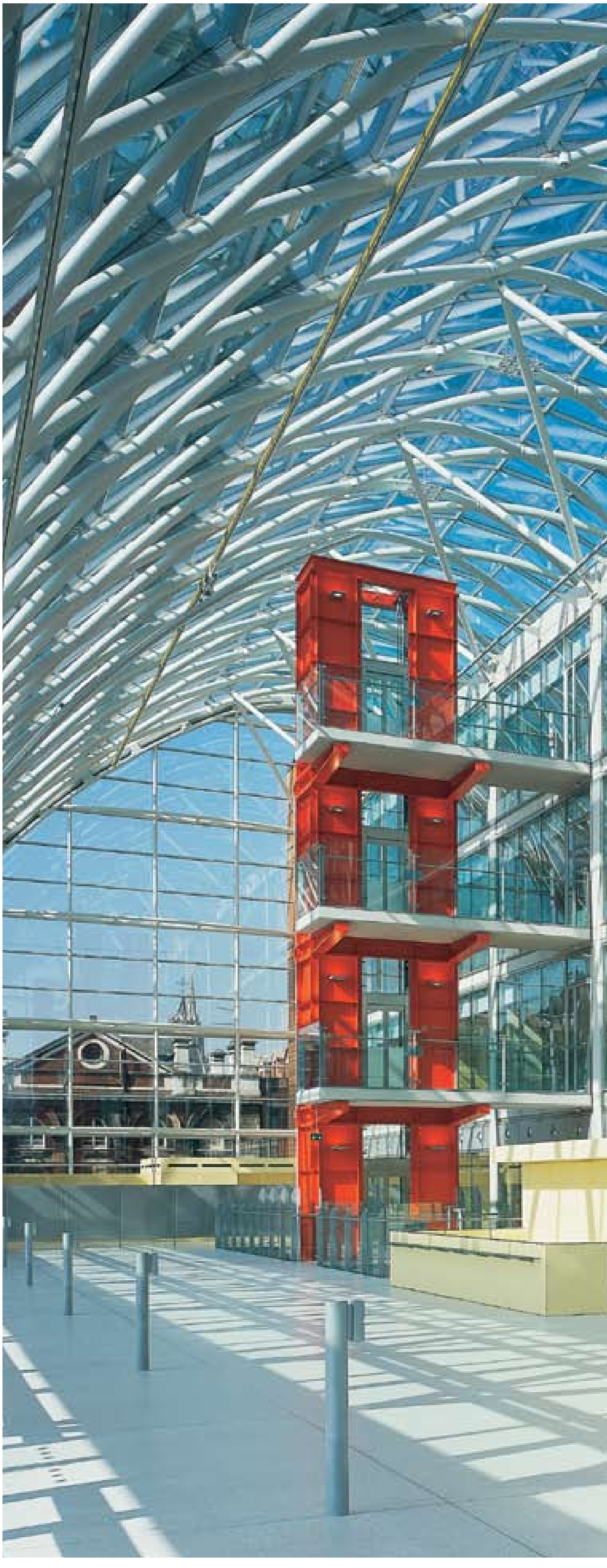
A Healing Place

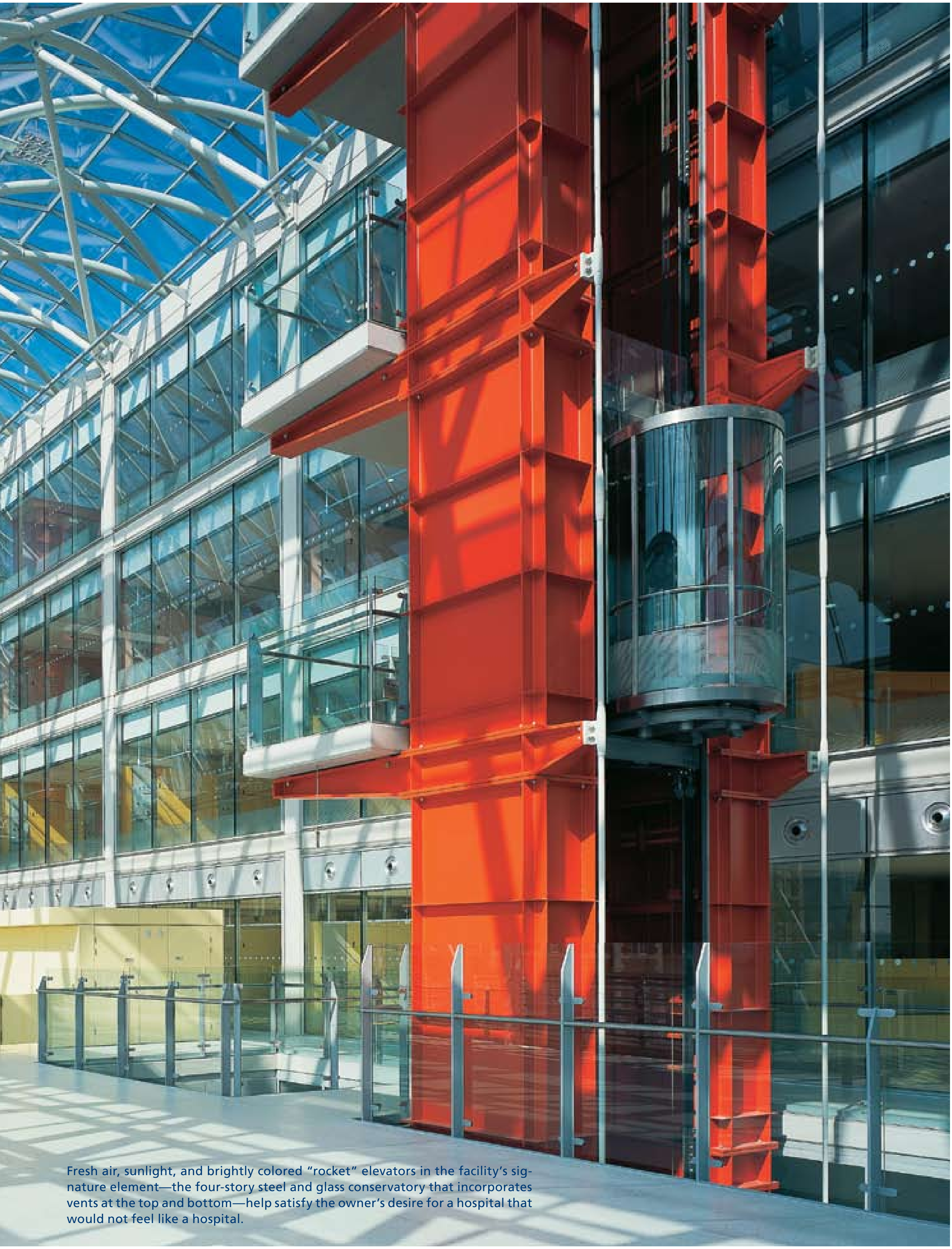
London's new Evelina Children's Hospital was designed with children in mind—and with input from children—to function as a medical facility like no other. Thanks to a cooperative working relationship between the architect and the structural engineer, the building that resulted is a state-of-the-art work of art. **By Robert L. Reid**



When it came time to design the new Evelina Children's Hospital—the first new children's hospital to be built in London in more than a century—the facility's owner wanted what may have seemed to be a contradiction in terms: a hospital that would not feel like a hospital. The owner—Guy's and St. Thomas' NHS Foundation Trust—also took an unconventional approach to selecting the team that would design and construct this unique facility. The trust funded a competition and allowed children, their families, and hospital staff members to participate in selecting the winner.

That competition, held in 1999, was the first to be managed by the Royal Institute of British Architects (RIBA) for a hospital under the United Kingdom's government-run health care system, the National Health Service (NHS). More than 50 architects initially competed for the project, 11 were interviewed by the assessment panel, 5 were invited to make a detailed presentation with their engineering partner, and the team comprising Hopkins Architects and the structural engineering firm Buro Happold, both based in London, was the unanimous winner. The project was then delivered via a design/build contract.

0885-7024-/06-0002-0034/$25.00 per article



Fresh air, sunlight, and brightly colored "rocket" elevators in the facility's signature element—the four-story steel and glass conservatory that incorporates vents at the top and bottom—help satisfy the owner's desire for a hospital that would not feel like a hospital.

Paul Tyagi, all photographs

The building that resulted from this process is a seven-story, 16,500 m^2 structure with a concrete frame and, along its south side, a four-story arched steel and glass conservatory featuring a roof that rises to curve over the hospital's top floor. This conservatory provides an abundance of natural light as well as fresh air through various vents to the outdoors. The hospital's concrete slab floors have been engineered to accommodate the current state of the art in medical equipment—as well as future equipment needs—and the facility features well-lit, curved corridors that, in contrast to traditional hallways, which can intimidate some patients, are open on one side. It also features a playground in the waiting area with a 5 m high spiral slide, two special freestanding glass-enclosed elevators that travel within bright red steel structures, and a school that enables children to continue their education within the hospital. Even the signs are child friendly, relying on colors, animal names, and parts of the natural world—the ocean, the sky, and mountains, for example—to clearly designate floors and wards for patients and staff who might speak any of approximately 140 languages.

In keeping with this attempt to make the often frightening hospital setting a bit more appealing to young patients, the new facility opened appropriately enough on October 31 with a Halloween party.

Despite its new location and contemporary appearance, however, the Evelina Children's Hospital is a venerable institution in London. It was founded in 1869 by Baron Ferdinand de Rothschild after his wife, Evelina, died in childbirth. Since then the hospital has been located at various sites, and most recently its services were divided between the owner's two other hospitals: Guy's Hospital, near London Bridge, and St. Thomas' Hospital, near Westminster Bridge, both on the south bank of the river Thames. The new building centralizes the hospital system's pediatric services at a single location, on land within the St. Thomas' campus, across the Thames from the Houses of Parliament.

Andrew Barnett, a Hopkins director, describes the site as "gritty, dense, and urban," lacking substantial green space and gaining little aesthetic benefit from its proximity to the Thames. For those reasons, the south side of the site was ideal: it overlooks the lush gardens of Lambeth Palace, the archbishop of Canterbury's seat in London. The design team quickly conceived a plan to borrow the landscape of the park and relate the building closely to the green space by locating the massive conservatory—roughly 20 m high, 18 m wide, and 70 m long—on the southern side of the building, where, says Barnett, "you feel you can almost touch the trees."

During the design phase the Hopkins architects—including Pamela Bate, a director whose own child was ill at the time—and the Buro Happold engineers considered input from groups who would work within or make use of the new facility. This included information gathered from children regarding the things they dislike about hospitals and the things they wanted to see in a new hospital. The architects sat in on some interviews with children conducted by Guy's and St. Thomas' NHS Foundation Trust, and the engineers reviewed transcripts

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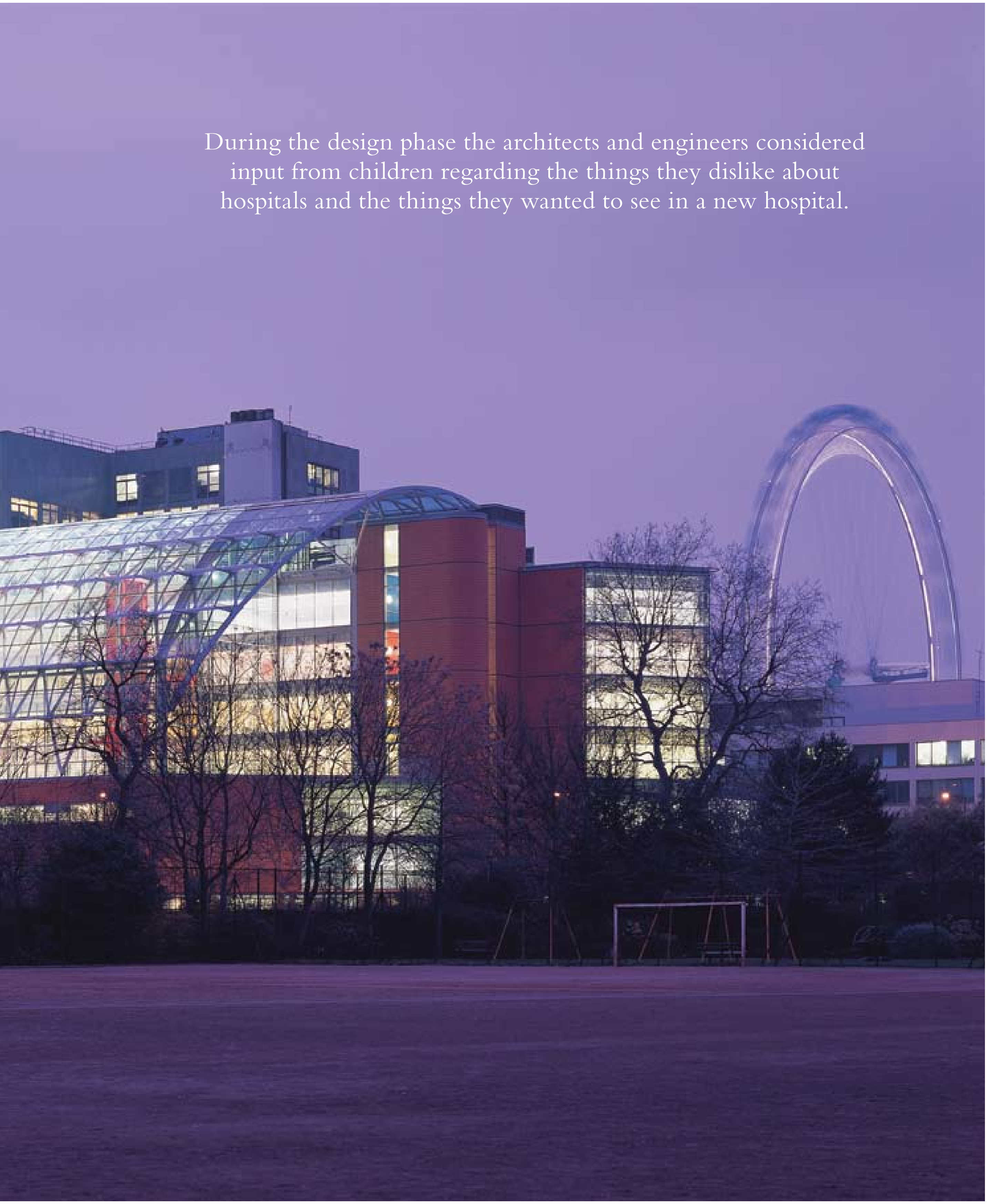


Though the site itself is largely urban, the south side overlooks the greenery of Lambeth Palace. The design team decided to make the most of this landscape by locating the glass conservatory where "you feel you can almost touch the trees," in the words of Andrew Barnett.

The free-standing elevators that rise through the heart of the building were an important part of the "fun" concept that helped the design team win the competition. The diagonal grid of the conservatory roof is constructed of 273 mm diameter tubular steel members of varying length.

of the interviews. One of the things that the Hopkins team heard from the children who were interviewed was the question, will we be able to breathe fresh air?

"That's a simple request," says Barnett. "But in most hospitals, you don't get fresh air. You're in an artificial environment for your length of stay."

To help grant that request, the conservatory features vents at its top and bottom to generate a natural airflow, as well as large light wells cut through the conservatory floor to channel daylight and natural ventilation into the heart of the building beneath. Additionally, all of the hospital wards line the back of the conservatory so that "a view is offered of everything going on in the conservatory and beyond into the park—but it's also a view toward the sunshine," Barnett says.

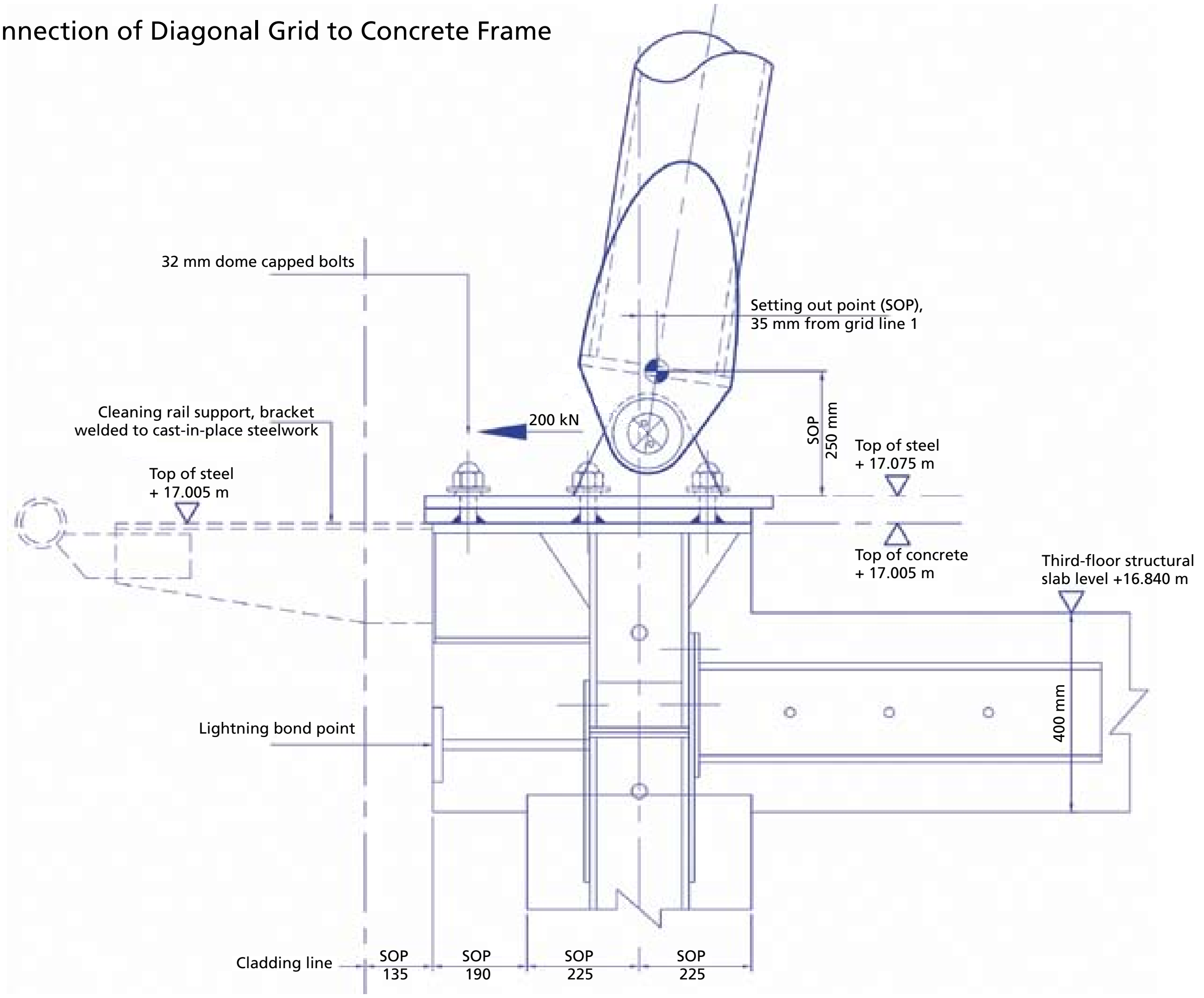
Michael Cook, Ph.D., CEng, a director of Buro Happold, says the basic ideas behind the design of the new hospital took shape during the RIBA competition and remained fairly consistent throughout the construction process. "If you look back at the architects' images of the final building and compare them to what was built, it's very close," he says. "We've all been very successful in sticking to those ideas that won the competition."

Many hospitals in the United Kingdom are designed in accordance with the Department of Health's private finance initiative (PFI). Here large contractors pay the costs of building health care facilities and then essentially lease the facilities back to the NHS over a period of 20 to 30 years. It's an approach that has generated "rather dull buildings that often do the job but don't inspire, delight, or charm anybody," adds Cook.

But the Guy's and St. Thomas' NHS Foundation Trust took a different approach, spending £50 million (U.S.$88 million) through the Guy's and St. Thomas' Charity to create "a more delightful, special building—a fantastically good opportunity to show what design can do for health care," says Cook. The NHS also spent £10 million (U.S.$18 million) on the project, and the Evelina Children's Hospital Appeal is raising another £10 million to provide the facility

The building's cladding—consisting of some 70,000 terra-cotta tiles—complements the surrounding buildings. The 6,500 m^2 of glass panels in the conservatory roof are shaded by a cantilevered system that also serves as a platform for cleaning and maintenance crews.

Connection of Diagonal Grid to Concrete Frame



Buro Happold

with furniture and medical equipment. Despite the hospital's innovative design, the facility actually cost slightly less than a typical PFI-procured building, notes Barnett.

Cook strongly believes that engineers should be involved in the design of a building from the time of its inception—from what he calls the blank-sheet-of-paper stage. That way, the engineers can assist the architects in determining, for example, whether a particular design feature can best be executed in concrete or steel. "We're at the table, so we can say, 'We think there might be a way you can do that,'" Cook explains. "That's one reason why we enjoy working with Hopkins—because they appreciate the benefits of doing that."

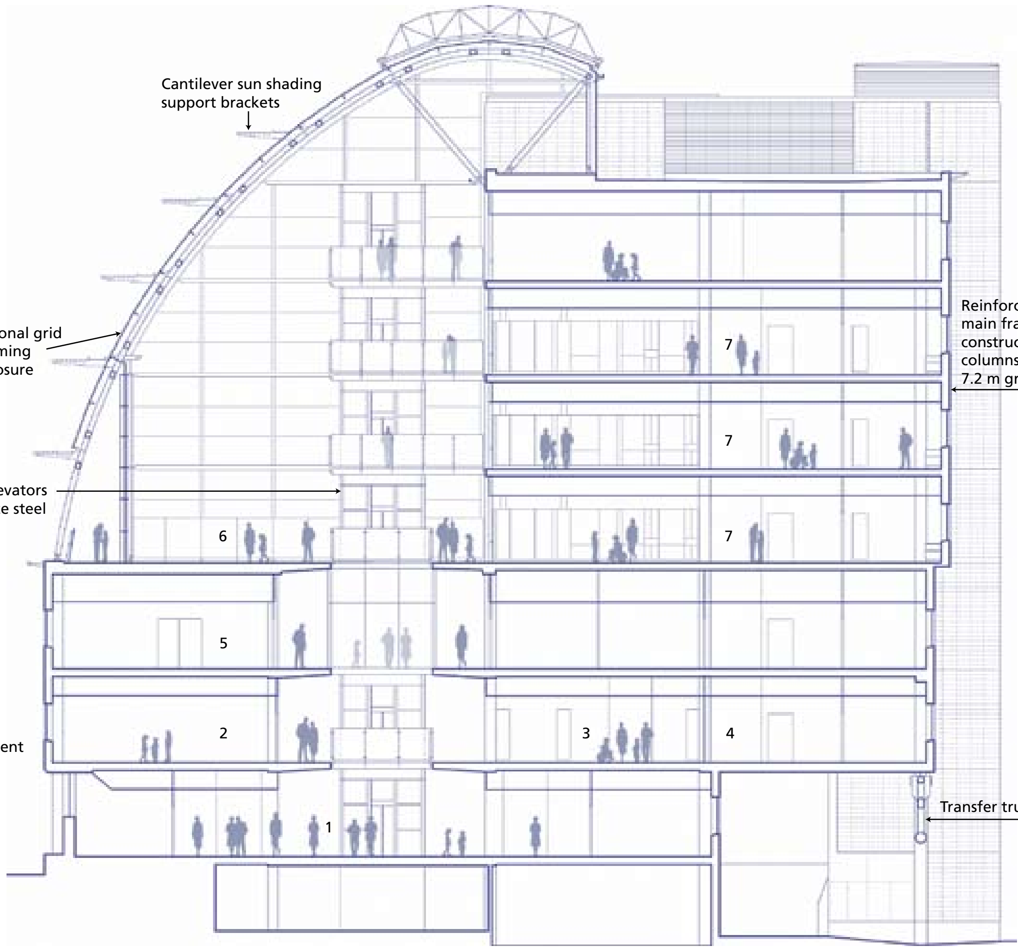
Cook says that this interplay between engineers and architects helped determine the final shape of the building's signature element—the massive glass and steel diagonal grid frame of the conservatory—and identified the need for the tubular steel props that were positioned near the top of the conservatory to greatly reduce the bending effects in the diagonal grid roof structure.

Such cooperation was also required of the general contractor and the hospital staff when it was discovered that the original plan for the building exceeded the site footprint, necessitating "a lot of very hard design work" and a great deal of give and take to reduce the size of the facility and complete it within the budget "while still delivering the vision we promised," says Barnett.

The construction contract for the hospital was awarded to the M.J. Gleeson Group, of London, in February 2002 and the site was prepared that March by first demolishing Riddell House, a five-story accommodation for nurses that had been built in the 1930s. The site is bordered on three sides by other wings and buildings of St. Thomas' Hospital, which made it a challenge to "shoehorn the building into the site itself," explains Matthew Grant, CEng, an associate with Buro Happold. For instance, the construction team had to cantilever a concrete wall over part of the foundation to support the column in the west corner of the site because a preexisting sewage pumping station stood on the spot specified for one of the foundation columns, Grant says.

The soil beneath the site is the stiff clay typical of London and extends down about 25 m. The site's proximity to the Thames meant that at high tide the groundwater would reach approximately basement level, Grant says. So the construction crews first installed temporary sheet-pile walls and dewatered the excavation site to *(continued on page 84)*

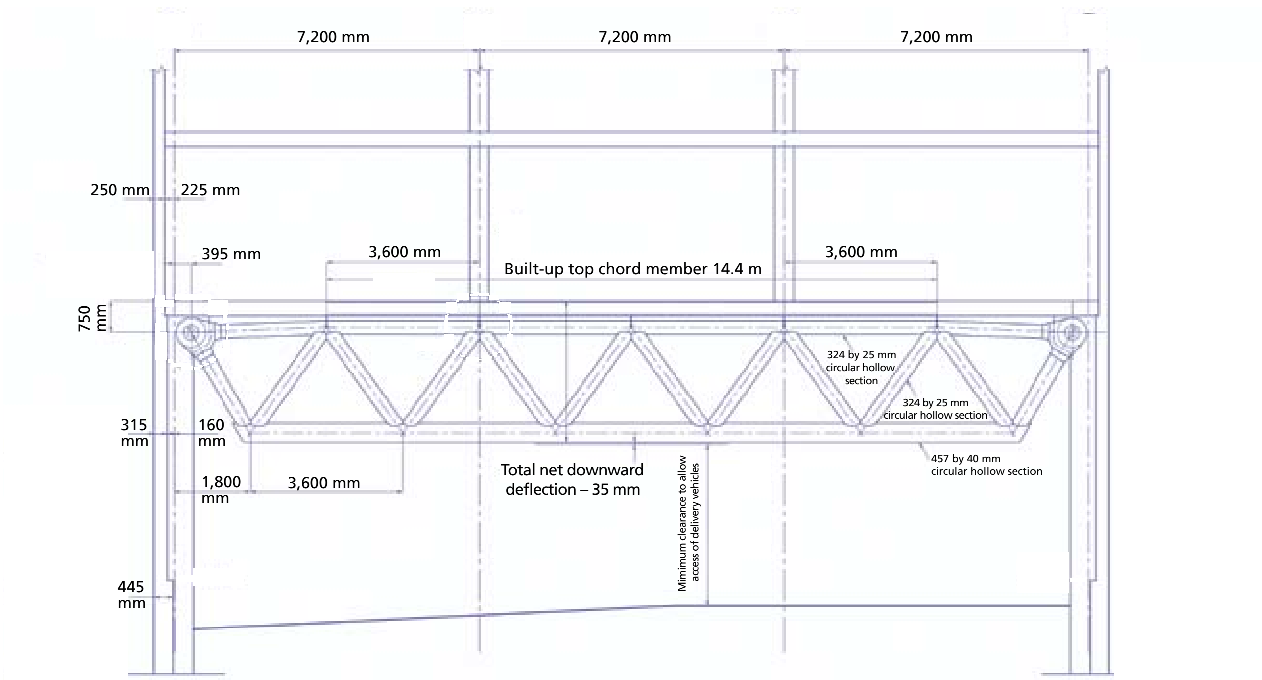
Cross Section



1. Shared waiting
2. Academic department
3. Medical day case ward
4. Renal outpatients department
5. Recovery
6. Conservatory
7. Ward

Hopkins Architects/Buro Happold

Elevation of Transfer Truss



Buro Happold

(continued from page 40) enable the deeper foundations for the building cores to be constructed. The building foundations consist of more than 300 rotary-bored piles—with diameters of 600 mm—founded in the London clay. The foundations are formed in clusters of three and four piles with a pile cap that transfers the column load into the piles. The largest column load is on the order of 11,000 kN. The contractor drove steel casings into the ground to form a watertight cutoff in the London clay to prevent water ingress while the pile was being bored, Grant says. A reinforcement cage was then inserted into the pile bore and the concrete was poured.

The London fire code requires that fire truck access be provided to both the back section of the new hospital and the nearby wing of St. Thomas' Hospital. Because of the size of the site, the only way to meet this requirement was to include a vehicular access way directly beneath the new hospital, says Grant. The structural solution involved replacing two columns in the building's column grid between the ground floor and the floor above with a transfer truss at the back of the building. The roughly 22 m long, 3.5 m high tubular steel Warren truss effectively supports the weight of the six-story concrete frame that rises directly overhead—the supported column loads being on the order of 500 Mg—while also opening up a space large enough for a fire truck to drive under the hospital, says Grant. The truss's deflection is restricted to 35 mm to maintain the required clearance between the ground floor and the floor above it for the fire equipment.

The most noticeable feature of Evelina's design—and the one most integral in realizing a hospital that would not feel like a hospital—is the conservatory with its roof of steel and glass.

Barnett notes that Hopkins believes strongly in the idea that the structure of a building should be exposed and expressed—that visitors should be able to see "what it's made of and how it stands up." With respect to the transfer truss, this approach meant that the truss needed to be aesthetically pleasing as well as functional, says Grant. The solution was found both in the tubular steel construction and in using single-pin end connections to fasten the truss to the fabricated steel columns. As the truss moves and deflects, the large steel pin connections transfer the gravity load to the fabricated steel columns without transferring any turning moments, Grant explains. Given the importance of the single-pin connections to the integrity of the truss structural system, the design incorporates a safety factor of twice the expected gravity loading, rather than the 1.4 and 1.6 recommended by the British design codes, Grant adds.

Work on the new hospital's concrete frame began in October 2002. The plan is rectangular and features a diagonal edge on the east face, where Lambeth Palace Road cuts across the site at an angle of roughly 45 degrees. The building grid is based on 9 by 7.2 m bays, with a span of 11.6 m between columns. The floor is a flat slab design with "downstand" beams—which project below the soffits of the slabs—positioned along the diagonal edge to limit deflections, Grant says.

The flat slabs are penetrated at key positions by mechanical or electrical systems as well as by specialized systems for medical equipment. Buro Happold engineers were mindful of the fact that hospitals often add or remove equipment from rooms and change the purposes for which rooms are used. "So we tried to provide as much flexibility within the design as we could," Grant says. This was done by casting a series of concrete-filled steel tubes within the slabs; the concrete filling is required for fire protection. "If you need to run a service through the slab again, all you have to do is pull up the raised access floor and you've got these tubes," Grant says. "Just knock the concrete through and you've got a number of tubes in there [for services] that they can use at future dates."

The flat slab design also creates an uninterrupted space for the horizontal distribution of services above a false ceiling, Grant notes. Service lines are carried vertically within the building's core.

The owner required connectivity between the new hospital and the east wing of St. Thomas'. The architects and engineers solved this problem by designing three glass-enclosed, tubular steel Warren truss bridges that link the ground floors of the two buildings and each of the two floors immediately above the ground floor. The bridges cross a space approximately 100 m long—supported by a combination of a tripod structure and intermediate H frames—and bend near the center to maneuver around an existing boiler house. Sliding connections between the concrete frame and the bridge trusses control movement and prevent the buildup of thermally induced axis loads in the bridge truss, Grant notes.

The most noticeable feature of Evelina's design—and the one most integral in realizing a hospital that would not feel like a hospital—is the conservatory with its roof of steel and glass. It is here that natural light and natural ventilation enter the hospital, that the hospital's school, a café, and a small outdoor garden are located, and that a pair of so-called rocket glass elevators rise through the heart of the building, somewhat like the elevator in the children's story "Charlie and the Chocolate Factory," notes Grant. This element was a key component of the concept of "fun" that helped Hopkins and Buro Happold win the design competition, he adds.

But it was also in the conservatory roof that the architects and engineers confronted some of their greatest challenges. The diagonal grid of that roof rises from the hospital's fourth story (called the third floor because the floor above the ground floor is considered the first), curving up and over the seventh floor. The grid is constructed of 273 mm diameter tubular steel members of varying wall thickness. On top of this grid sits a series of steel frames that run across the grid orthogonally, spaced 2.4 m apart *(continued on page 86)* *(continued from page 84)* on center. Rectangular glazed panels—roughly 2.4 m long by 1.2 m wide—are bolted into these frames; slotted connections link the frames to the diagonal grid members to prevent forces from transferring to the glazing, explains Grant. The grid was erected and welded on-site during the spring and summer of 2004. The glass panels were bolted on early in 2005, and the interior work was completed last fall.

The radius of curvature of the roof varies but is roughly 35 m. The gravity loads—imposed by the glazing system and the steel structure—are predominantly carried by bending in the grid members, Grant notes.

The exposed structural connections between the grid roof and the building's concrete frame were developed jointly by the architects and the engineers and serve as a good example of how structure can be given architectural expression, Grant notes. They did, however, constitute a complicated detail given the difficulty of connecting steel to concrete, especially when large forces are involved.

"One of the things we had to contend with was the fact that concrete is constructed to a lot looser tolerances than steel," Grant explains. "Steel can be constructed very accurately—probably to within about two and five millimeters of tolerance—whereas concrete is constructed within about fifteen millimeters of tolerance."

But a concrete frame was necessary for reasons of cost and fire resistance, and it was necessary to use steel in the roof because of its strength-to-weight ratio, which also made the complicated curvature possible. The architecture and engineering team needed to produce a connection that could accommodate the tolerances of the two materials while being able to deal with the significant force transfer between the steel roof and the concrete frame. A rigid connection would have transferred a turning moment into the concrete frame every time the roof moved, Grant notes, so the team chose a pinned connection to limit the force transfer to just the high vertical and horizontal forces coming down through the roof. These forces are transferred into the concrete frame via 16 pinned connections attached to large steel I sections that were embedded within the concrete slab and columns.

The grid was designed to withstand snow, thermal, and wind loadings, as well as the loads of a cleaning gantry, Grant notes. Deflection across the entire 6,500 m^2 of glass panels was limited to roughly 25 mm, sufficient to prevent water leakage through the glazing seals, he says.

The glazing subcontractor was involved early in the process of designing the roof structure, providing a reality check of sorts, Grant notes.

The conservatory roof required two other types of connections: between the curving grid and the vertical end walls and between the grid—which extends to the edge of the building floor plate—and the long vertical wall of the conservatory facade, which is slightly inboard. (There is a small walkway between the edge of the floor plate and the facade).

In designing the end walls, the team allowed for horizontal tolerances to be taken up through a connection that utilizes a system of steel shim plates between two thicker steel plates and accommodated vertical movement through a 30 mm gap at the base of the connection, Grant explains. In the grid-to-facade connection, an articulated joint supports the top of the wall and enables the roof to move independently of the wall and without exerting any forces on the wall, Grant says.

Although the conservatory's glass walls are designed to admit sunlight into the hospital, the design team also had to ensure that this feature of the facility's southern exposure did not produce excessive heat gain—especially since the facility uses little air-conditioning, Grant explains. So a passive sun shading system was erected on the exterior of the glazing. Four walkwaylike cantilevered structures protrude roughly 1.2 m from the glass panels and run the length of the conservatory, providing horizontal shading as well as a platform for cleaning or maintenance crews. At the top of the curving roof, where a horizontal shade would have been impractical, a traveling gantry is used to clean the glazing. Here fritted glazing—which incorporates a pattern of ceramic circles baked onto the surface of the glass—helps shade the interior, Barnett says.

Around the exterior of the building some 70,000 terra-cotta tiles form the rain screen cladding, hanging from carrier rails that are bolted to the concrete frame. In addition to providing a cavity between the cladding and the framing—which facilitates airflow to reduce moisture—the tiles are in keeping with the preference of the Hopkins architects to use low-maintenance, natural materials in the buildings they design. Additionally, the terra-cotta complements the surrounding buildings of St. Thomas' Hospital, which are distinguished by orange brickwork dating to the 19th century and white ceramic tile on buildings constructed in the late 20th century.

The architects and engineers who designed the Evelina Children's Hospital clearly take great pride in the vision they brought to fruition and have nothing but the highest of hopes for their creation. Cook, for one, believes that such a "delightful" building will attract and retain the highest quality staff. Of even greater importance, both Cook and Barnett view the physical structure of the hospital in almost metaphysical terms and expect the building itself to help patients recover sooner by providing them with a more pleasant, natural environment in which to convalesce. ■

PROJECT CREDITS

Owner: Guy's and St. Thomas' NHS Foundation Trust, London

Architect: Hopkins Architects, London

Structural engineer and fire safety design: Buro Happold, London

Building services engineer: Hoare Lea, London

Main contractor: M.J. Gleeson Group, London

Glazier: Klaus Fischer, Ltd., Middlesex, United Kingdom